ART OF BUILDING

WEALE'S SCIENTIFIC & TECHNICAL SERIES

EDWARD DOBSON

NEW EDITION BY

J. PARNELL ALLEN

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VOL.

RUDIMENTS OF THE

ART OF BUILDING

INCLUDING

THE GENERAL PRINCIPLES OF CONSTRUCTION, THE CHARACTER, STRENGTH, AND USE OF MATERIALS, PREPARATION OF SPECIFICATIONS AND ESTIMATES, ETC. ETC.

BY EDWARD DOBSON

MEMBER OF THE INSTITUTION OF CIVIL ENGINEERS

FIFTEENTH EDITION

REVISED TO DATE, WITH AN ADDITIONAL SECTION ON "AN IDEAL DWELLING"

BY JOHN PARNELL ALLEN

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With numerous Illustrations

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EXTRACT FROM
PREFACE TO FIRST EDITION.

THIS little volume is intended as "a first book" for the use of students who are about to commence their professional training for any pursuit connected with the erection of buildings; and, also, for the use of amateurs who wish to obtain a general knowledge of the subject without devoting to it the time requisite for the study of the larger works that have been written on the different branches of construction.

To avoid unnecessarily extending the limits of the work, not a few subjects are omitted which are treated of in other volumes of Weale's Series, and to these works the attention of the reader is invited. A full list of Weale's Series wil be found in the Publishers' Lists at the end of the present volume.

PUBLISHERS' ADVERTISEMENT.

MR. EDWARD DOBSON, to whom the Publishers of Weale's Series were indebted for the excellent little volume on the "ART OF BUILDING"—which has now passed through fourteen large editions—having been for many years resident in New Zealand, the Publishers have had no opportunity of engaging his services for the revision of the work which was found needful to bring it into full accord with modern practice; and under these circumstances the revision has been entrusted to Mr. J. P. ALLEN, who has not only carefully revised the text throughout with that view, but has added an additional section on "An Ideal Dwelling," which cannot fail to enhance the interest and utility of the work.

LONDON, *October*, 1901.

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RUDIMENTS

OF THE

ART OF BUILDING.

SECTION I.

GENERAL PRINCIPLES OF CONSTRUCTION.

FOUNDATIONS.

1. In preparing the foundation for any building, there are two sources of failure which must be carefully guarded against: viz., inequality of settlement and lateral escape of the supporting material; and, if these radical defects can be guarded against, there is scarcely any situation in which a good foundation may not be obtained.

2. *Natural Foundations.*—The best foundation is a *natural* one, such as a stratum of rock, or compact gravel. If circumstances prevent the work being commenced from the same level throughout, the ground must be carefully *benched out*, that is, cut into horizontal steps, so that the courses may all be perfectly level. It must also be borne in mind that all work will settle, more or less, according to the perfection of the joints, and therefore in these cases it is best to bring up the foundations to a uniform level, with large

blocks of stone, or with concrete, before commencing the superstructure, which would otherwise settle most over the deepest parts, on account of the greater number of mortar joints, and thus cause unsightly fractures, as shown in Fig. 1.

3. Many soils form excellent foundations when kept from the weather, which are worthless when this cannot be effected. Thus blue shale, which is often so hard when the ground is first opened as to require blasting with gunpowder, will, after a few days' exposure, slake and run into sludge. In dealing with soils of this kind nothing is required but to keep them from the action of the atmosphere. This

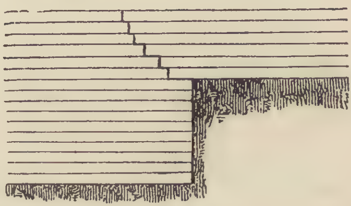


Fig. 1.

is best done by covering them with a layer of concrete, which is an artificial rock, made of sand and gravel, cemented with a small quantity of lime. For want of this precaution many buildings have been fractured from top to bottom by the expansion and contraction of their clay foundations during the alternations of drought and moisture, to which they have been exposed in successive seasons.

4. *Artificial Foundations.*—Where the ground in its natural state is too soft to bear the weight of the proposed structure, recourse must be had to artificial means of support, and, in doing this, whatever mode of construction be

adopted, the principle must always be that of extending the bearing surface as much as possible; just in the same way that by placing a plank over a dangerous piece of ice a couple of men can pass over a spot which would not bear the weight of a child. There are many ways of doing this —as by a thick layer of concrete, or by layers of planking, or by a network of timber, or these different methods may be combined. The weight may also be distributed over the entire area of the foundation by inverted arches, and this is especially advisable where you have a large building full of openings, and the weights of floors, etc., brought to the piers. Inverted arches are then more than ever necessary to prevent unequal settlement, by re-distributing the weights on to the full area of foundation.

5. The use of timber is objectionable where it cannot be kept constantly wet, as alternations of dryness and moisture soon cause it to rot, and for this reason concrete is very extensively used in situations where timber would be liable to decay.

6. In the case of a foundation partly natural and partly artificial, the utmost care and circumspection are required to avoid unsightly fractures in the superstructure; and it cannot be too strongly impressed on the mind of the reader, that it is not an *unyielding*, but a *uniformly yielding* foundation that is required, and that it is not the *amount*, so much as the *inequality*, of settlement that does the mischief.

The second great principle which we laid down at the commencement of this section was—To prevent the lateral escape of the supporting material. This is especially necessary when building in running sand, or soft buttery clay, which would ooze out from below the work, and allow the superstructure to sink. In soils of this kind, in addition to

protecting the surface with planking, concrete, or timber, the whole area of the foundation must be inclosed with wood or cast-iron piles driven close together—this is called *sheet-piling.* The cast-iron sheet piling is arranged as sketch, Fig. 1A.

PLAN
Fig. 1A.

Where running sand or soft irregular ground is met with, and where the site is so inclosed that piling could not be conveniently undertaken, and provided the neighbouring drains and sewers were not so deep as to run a risk of drawing off the water in the foundation, a block of concrete several feet thick should be spread over the whole site with cross-laced layers of steel rods, joists, old railway

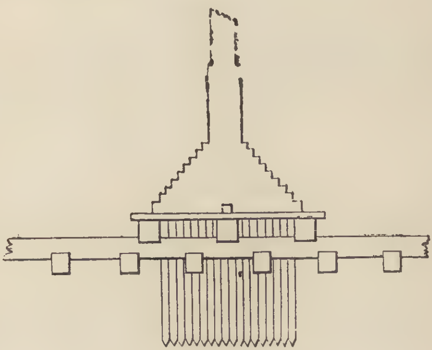


Fig. 2.

rails, or expanded metal, placed below the neutral axis in the lower portions of the concrete to give the block that resistance to tension which it would lack if the ground underneath were to settle unevenly.

An example of a wide-spread foundation in soft ground is shown in Fig. 2, which is a section of the founda-

tion for the walls of the Leyden station of the Amsterdam and Rotterdam Railway, built A.D. 1843.* The station stands upon such bad ground, that it was necessary to support the walls upon a kind of raft resting on oak piles.

7. Where there is a hard stratum below the soft ground, but at too great a depth to allow of the solid work being brought up from it without greater expense than the circumstances of the case will allow, it is usual to drive down wooden piles, shod with iron, until their bottoms are firmly fixed in the hard ground. The upper ends of the piles are then cut off level, and covered with a platform of timber on which the work is built in the usual way.

8. Where a firm foundation is required to be formed in a situation where no firm bottom can be found within an available depth, piles are driven, to consolidate the mass, a few feet apart over the whole area of the foundation, which is surrounded by a row of sheet-piling to prevent the escape of the soil; the space between the pile heads is then filled to the depth of several feet with stones or concrete, and the whole is covered with a timber platform, on which to commence the solid work.

9. *Foundations in Water.*—Hitherto we have been describing ordinary foundations; we now come to those cases in which water interferes with the operations of the builder, oftentimes causing no little trouble, anxiety, and expense.

Foundations in water may be divided under three heads: 1st, Foundations formed wholly with piles. 2nd, Solid foundations laid *on* the surface of the ground, either in its natural state, or roughly levelled by dredging. 3rdly, Solid foundations laid *below* the surface, the ground being laid dry by cofferdams.

* From the "Minutes of Proceedings of the Institution of Civil Engineers," 1844.

10. *Foundations formed wholly of piles.*—The simplest foundations of this kind are those formed by rows of wooden piles braced together so as to form a skeleton pier for the support of horizontal beams; and this plan is often adopted in building jetties, piers of wooden bridges, and similar erections where the expense precludes the adoption

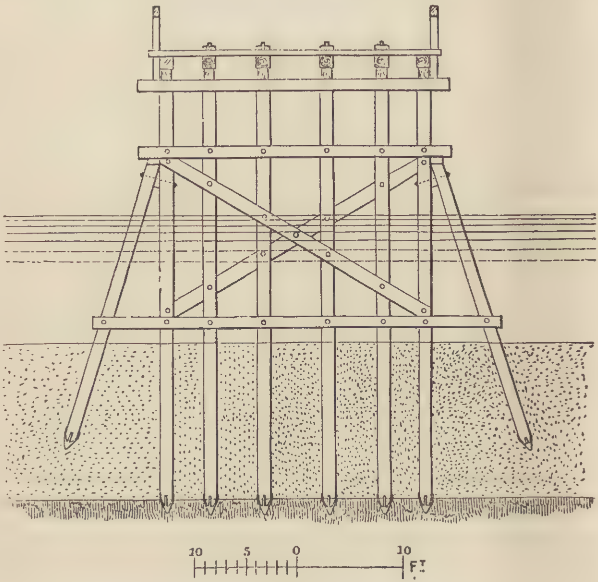


Fig. 3.

of a more permanent mode of construction; an example of this kind is shown in Fig. 3.

In deep water the bracing of the piles becomes a difficult matter, and an ingenious expedient for effecting this was made use of by Mr. Walker, in the erection of the Ouse Bridge, on the Leeds and Selby Railway, A.D. 1840. This

consisted in rounding the piles to which the braces are attached for a portion of their length, to allow the cast-iron sockets in which they rest to descend and take a solid bearing upon the square shoulders of the brace-piles. After the brace-piles were driven, the braces were bolted into their sockets and dropped down to their required position, and their upper ends were then brought to their places and bolted to the superstructure.

11. There is always, however, a great objection to the use of piles partly above and partly under water, namely, that, from the alternations of dryness and moisture, they soon decay at the water-line, and erections of timber require extensive repairs from this cause. In tidal waters, too, they are often rapidly destroyed by the worm, unless the timber is impregnated with solutions to preserve it from decay and worm destruction, the best known processes being creosoting, burnettising, kyanising, and haskenising.

To obviate the inconveniences attending the use of timber, cast iron is sometimes used as a material for piles; but this again is objectionable in salt water, as the action of the sea-water upon the iron converts it into a soft substance which can be cut with a knife, resembling the Cumberland lead used for pencils.

12. In situations where a firm hold cannot be obtained for a pile of the ordinary shape, such as shifting sand, Mitchell's patent screw-piles may be used with great advantage. These piles terminate at the bottom in a large iron screw, 4 ft. in diameter, which, being screwed into the ground, gives a firm foothold to the pile. This is a very simple and efficient mode of obtaining a foundation where all other means would fail, and has been used in erecting light-houses on sand-banks with great success. The Maplin Sand Lighthouse at the mouth of the Thames, and

the Fleetwood Lighthouse, at Fleetwood, in Lancashire, both erected A.D. 1840, may be instanced.

13. An ingenious system of cast-iron piling was adopted by Mr. Tierney Clark, in the erection of the Town Pier at Gravesend, Kent, A.D. 1834, in forming a foundation for the cast-iron columns supporting the superstructure of the T head of the pier. Under the site of each column were driven three cast-iron piles, on which an adjusting plate was firmly keyed, forming a broad base for the support of the column, which was adjusted to its correct position, and bolted down to the adjusting plate.

14. A kind of foundation on the same principle as piling has been lately much used in situations where ordinary piling cannot be resorted to with advantage. The method referred to consists in sinking hollow cast-iron cylinders until a hard bottom is reached. The interior of the cylinder is then pumped dry, and filled up with concrete or some equally solid material, thus making it a solid pier on which to erect the superstructure. The cylinders are made in lengths, which are successively bolted together as each previous length is lowered, the excavation going on at the bottom, which is kept dry by pumping. It often happens, however, in sinking through sand, that the pressure of the water is so great as to blow up the sand at the bottom of the cylinder; and, when this is the case, the operation is carried on by means of a large auger, called a miser, which excavates and brings up the materials without the necessity of pumping out the water. The lower edge of the bottom length of each cylinder is made with a sharp edge, to enable it to penetrate the soil with greater ease, and to enter the hard bottom stratum on which the work is to rest. This method was adopted by Mr. Redman in the erection of the Terrace Pier at Gravesend, Kent, finished A.D. 1845,

and the same principle is adopted in tunnelling with cast-iron tubes for underground railways.

15. Before closing our remarks on pile foundations, we must mention a very curious system of carrying up a foundation through loose wet sand, which is practised in India and China, and is strictly analogous to the sinking of cast-iron cylinders just described.

It consists in sinking a series of wells close together, which are afterwards arched over separately, and covered with a system of vaulting on which the superstructure is raised. The method of sinking these wells is to dig down, as far as practicable, without a lining of masonry, or until water is reached; a wooden curb is then placed at the bottom of the excavation, and a brick cylinder raised upon it to the height of 3 or 4 ft. above the ground. As soon as the work is sufficiently set, the curb and the superincumbent brick-work are lowered by excavating the ground under the sides of the curb, the peculiarity of the process being that the well-sinker works under water, frequently remaining submerged more than a minute at a time. These cylinders have been occasionally sunk to a depth of 40 ft.

16. *Solid Foundation simply laid on the Surface of the Ground.*—Where the site of the intended structure is perfectly firm, and there is no danger of the work being undermined by any scour, it will be sufficient to place the materials on the natural bottom, the inequalities of surface being first removed by dredging or blasting.

17. *Pierre perdue.*—The simplest mode of proceeding is to throw down masses of stone at random over the site of the work until the mass reaches the surface of the water, above which the work can be carried on in the usual manner. This is called a foundation of "*pierre perdue*," or

random work, and is used for breakwaters, foundations of sea-walls, and similar works. Plymouth breakwater is an example on a large scale.

18. *Coursed Masonry.*—Another way much used in harbour work, is to build up the work from the bottom (which must be first roughly levelled) with large stones, carefully lowered into their places; and this is a very successful method where the stones are of sufficient size and weight to enable the work to withstand the run of the sea. The diving-bell affords a ready means of verifying the position of each stone as it is lowered.

19. *Béton.*—On the Continent foundations under water are frequently executed with blocks of béton or hydraulic concrete, which has the property of setting under water. The site of the work is first inclosed with a row of sheet-piling, which protects the béton from disturbance until it has set. This system is of very ancient date, being described by Vitruvius, and was practised by the Romans, who have left us many examples of it on the coast of Italy. The French engineers have used béton in the works at Algiers, in large blocks of 324 cubic feet, which were floated out and allowed to drop into their places from slings. This method, which proved perfectly successful, was adopted in consequence of the smaller blocks first used being displaced and destroyed by the force of the sea.

20. *Caissons.*—A caisson is a chest of timber, which is floated over the site of the work, and, being kept in its place by guide-piles, is loaded with stone until it rests firmly on the ground. The masonry is then built on the bottom of the caisson, and when the work reaches the level of the water the sides of the caisson are removed.

This method of building has been much used on the Continent, but is not much practised in this country.

Westminster Bridge, London, is a noted instance of its failure. The bottom of the river has been scoured out to a depth of several feet since the erection of the bridge; and the foundations of the piers remained in a dangerous state until they were secured in the recent repairs by driving sheet-piling all round them, and underpinning the portions which had been undermined.

21. An improvement on the above method consists in dredging out the ground to a considerable depth, and putting in a thick layer of béton on which to rest the bottom of the caisson.

22. There is a third method of applying caissons which

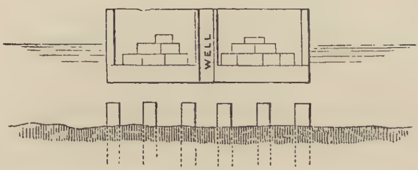


Fig. 4.

is practised by our Continental neighbours, and which is free from the objections which commonly attend the use of caissons. A firm foundation is first formed by driving piles a few feet apart over the whole site of the foundation. The tops of the piles are then sawn off under water just enough above the ground to allow of their being all cut to the same level. The caisson is then floated over the piles, and, when in its proper position, is sunk upon them, being kept in its place by a few piles left standing above the others, the water being kept out of the caisson by a kind of well constructed round each of these internal guide-piles, which are built up into the masonry. This method of building in caissons on pile foundations is shown in Figs. 4

and 5. The piers of the Pont du Val Benoît at Liége, built A.D. 1842, which carries the railway across the Meuse, have been built on pile foundations in the manner here described.

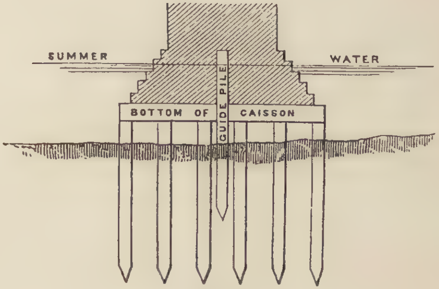


Fig. 5.

23. *Solid Foundations laid in Cofferdams.*—There are many circumstances under which it becomes necessary to lay the bottom dry before commencing operations. This is done by inclosing the site of the foundation with a water-

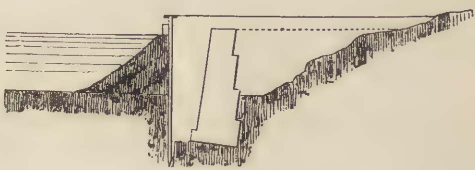


Fig. 6.

tight wall of timber, from within which the water can be pumped out by steam power or otherwise. Sometimes, in shallow water, it is sufficient to drive a single row of piles only, the outside being protected with clay, as shown in Fig. 6; but in deep water two or even four rows of piles

will be required, the space between them being filled in with well-rammed *puddle*, so as to form a solid watertight mass (see Fig. 7). The great difficulties in the construction of a cofferdam are—1st to keep it water-tight; and, 2nd, to support the sides against the pressure of the water outside, which in tidal waters is sometimes so great as to render it necessary to allow a dam to fill to prevent its being crushed.

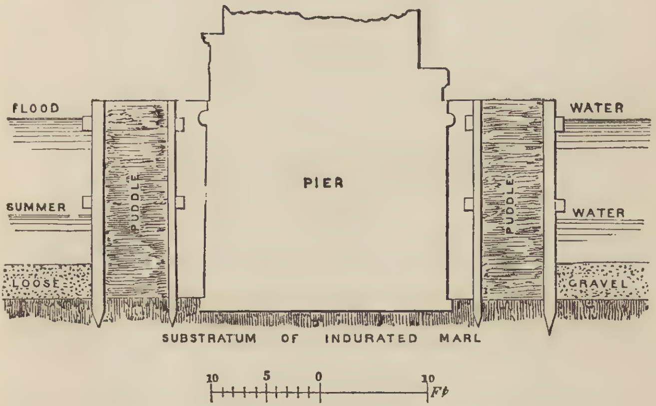


Fig. 7.

24. In order to save timber, and to avoid the difficulty of keeping out the bottom springs, it has been proposed by a French engineer, after driving the outer row, to dredge out the area thus inclosed, and fill it up to a certain height with béton. The cofferdam is then to be completed by driving an inner row of piles resting on the béton, and puddling between the two rows in the usual manner; and the masonry is carried up on the béton foundation thus prepared. This construction is shown in Fig. 8.

25. The limits of the present volume prevent our entering into any detail as to the preparation of concrete and béton, the methods in use for driving piles, and the construction of cofferdams: the reader who wishes to pursue

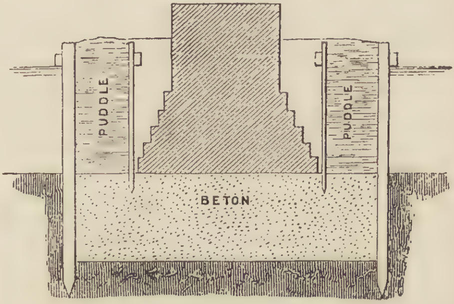


Fig. 8.

the subject further is referred to the volume of this series on "Foundations and Concrete Works," where he will find a detailed description of these operations.

RETAINING WALLS.

26. The name of retaining wall is applied generally to all walls built to support or sustain a mass of earth in a vertical position; but the term is, correctly speaking, applicable only to those constructed for the purpose of retaining earth or other filling deposited behind the wall after it is built (Fig. 9). Walls to prevent the fall of earth from its natural position in banks, etc., which have been excavated to a vertical or inclined face, are called face or breast walls, and need not be so thick as a retaining wall, as the undisturbed and consolidated earth exerts little or no lateral pressure (Fig. 10).

27. *Retaining Walls.*—Many rules have been given by different writers for calculating the thrust or pressure which a mass of earth may exert against a retaining wall, and for determining the most economical formation of wall to resist it; but the local conditions as to the nature of the bed formation, the materials available for filling and their action under different climatic influences, must be taken into account in applying theoretical deductions, and practical experience is desirable to successfully design work of this nature.

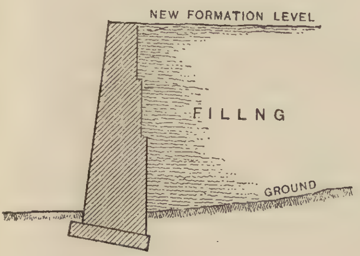


Fig. 9.

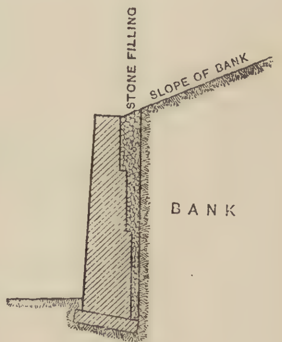


Fig. 10.

28. The calculation of the stability of a retaining wall involves the following investigations:—

(1) The pressure of the earth to be sustained.

(2) The liability of the wall to slide on its base.

(3) The overturning of the wall by rotating on its toe as a fulcrum, or failing by bulging out.

29. *Theory of earth pressure.*—The slope which the earth would assume if left totally unsupported is called the angle of natural slope, and is generally stated in term of degrees

relative to a horizontal line. The natural slope of different materials used for backing averages :—

Dry sand . .	34°	Gravel and shingle .	40°
Rubble . .	45°	Compact earth	45° to 50°
Well-drained clay	45°	Vegetable earth .	28°

For purposes of calculation it is recommended that the backing be assumed to have a natural slope of $1\frac{1}{2}$ hor. to 1 vert. : equal to an angle of nearly 34°, or the same as dry sand. To prevent the backing becoming saturated with water into a semi-fluid state, and thus bringing a hydrostatic pressure against the wall, in cases where this is likely to occur, weep holes or pipes should be built in the lower portion of the wall from back to front at regular intervals along its length.

In Fig. 11 the line B C denoting the natural slope of the backing and A B the face of back of wall, if the angle A B C

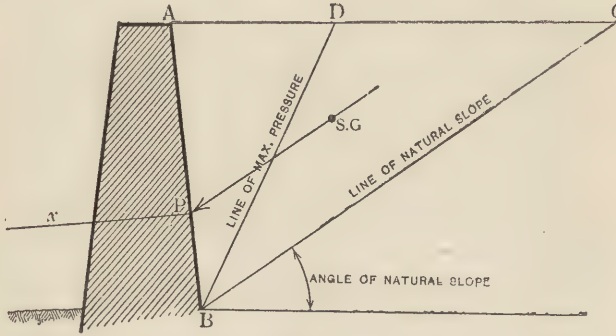


Fig. 11.

be divided into two equal angles by a line B D, then the angle A B D represents the angle, and B D the slope of maximum pressure ; because, considered as a wedge, the

mass contained in the triangle A B D produces a greater pressure upon the wall than the larger triangle A B C, considered as a single wedge, for although the latter is heavier, it is partially supported by the ground below it.

The centre of pressure is that point in which a straight line drawn parallel to the angle of natural slope through the centre of gravity of the mass contained in the triangle A B C, strikes the back of wall at P, and the direction of the pressure is at right angles to this face as P x.

When the ground is to be level with the top of wall, and the back face vertical, the centre of pressure P is one-third the height of the wall measured from the base.

The contents of the prism of maximum pressure (that is the area of the triangle A B D in square feet multiplied by a lineal length of one foot) multiplied by the weight per cubic foot of the material to be used for backing, represents the weight of earth to be sustained; and neglecting friction or cohesion of the material itself—assume W as weight of earth, b length of A D, and h height A B:

Then P x or theoretical pressure due to sustained earth per lineal foot $= \frac{W \times b}{h}$.

30. *Wall sliding upon its base or sinking.*—The ground should be excavated to give the base a firm hold in the ground, usually about 3 feet in railway work. When the ground is very soft, piles should be driven to hard ground in sufficient numbers to safely carry the weight or pressure calculated to come upon them, due to the weight of wall and sustained earth (Fig. 12).

WEIGHT OF MATERIALS IN LBS. PER CUBIC FOOT APPROXIMATELY.

Dry sand	90—100	Clay	120
Wet sand	120—170	Earth	80—120
Shingle	80	Marl	100—120

31. *Stability of Walls.*—The wall is assumed to be a solid mass incapable of sliding forward, and giving way only by overturning at its toe as a fulcrum. In the diagram (Fig. 13) the foundation of the wall has been omitted to simplify the consideration of the subject.

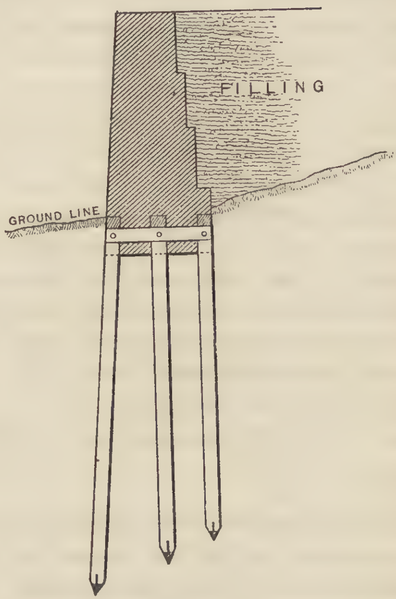


Fig. 12.

Find the centre of gravity of the wall and also the earth contained in the angle A B E (or the wall only if the back face is vertical) and draw a perpendicular line down through the base; where this line cuts the line of pressure P x, at the point a, with suitable scale make a b equal to the weight per lineal foot of wall, etc., and a c equal to earth pressure as previously ascertained. Complete the parallelo-

gram *a b d c* and draw the diagonal *f*, which will represent the resultant pressure in direction and magnitude. If this line falls outside the base B *o*, then the wall will be unstable. According to some authorities this line should fall between the middle third of the base; and others state, the length *f o* should not be less than one-fifth of the width of base B *o*,

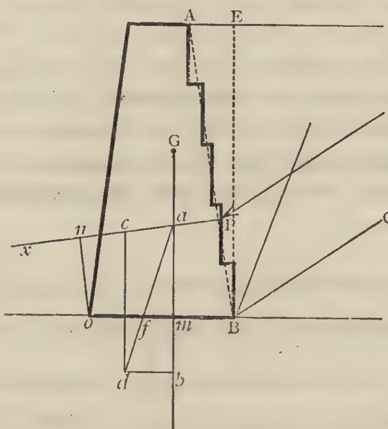


Fig. 13.

to prevent the wall sinking into the earth or fracturing the material of which the wall is built.

32. The moment of the wall to resist overturning will be the weight multiplied by the leverage *m o*.

Approximate Weight per Cubic Foot of Materials Used in Constructing Walls.

	lbs.
Brickwork	112—120
Masonry	115—150
Cement concrete	130—140

The moment of the pressure tending to overturn the wall, will be the pressure multiplied by the leverage *n o*

($n\,o$ being a line drawn at right angles to P x from the toe of the wall).

The stability of the wall will be in proportion as the moment of resistance exceeds the moment of pressure.

33. Where the friction of the earth against the slope and the back of the wall is destroyed by the filtration of water, the action of the earth will be precisely similar to that of a column of water of the height of the wall. The pressure upon the side of any vessel is the half of the pressure that would take place upon the bottom if of the same area. Now, calling the specific gravity of the water s, and vertical height h, the pressure upon the bottom, supposing its length to be l, would be $h\,s\,l$; therefore the pressure upon the side will be—

$$\frac{h\,s\,l}{2}\text{; and overturning moment} = \text{P} \times n\,o = \frac{h\,s\,l.\,n\,o}{2}$$

And, where the back of the wall is vertical, then—

$$\text{A B} = h \text{ and } n\,o = \frac{h}{3}. \quad \text{Therefore—}$$

$$\text{P} = \frac{h^2\,s}{2} \text{ and overturning moment} = \frac{h^2\,s}{2} \times \frac{h}{3} = \frac{h^3\,s}{6}$$

34. *Resistance of the Wall.*—Considering the wall as a solid mass, the effect of its weight to resist an overturning thrust will be directly as the horizontal distance E H from its front edge to a vertical line drawn through G, the centre of gravity of the wall, Fig. 14; or calling the moment R, and the weight of the wall w, then $\text{R} = w \times \text{E H}$. E H will be directly as E B, the proportions of the wall being constant; therefore a wall of triangular section will afford more resistance than a rectangular one of equal sectional area, the base of a triangle being twice that of a rectangle of equal height and area.

35. If the wall be built with a curved concave batter, Fig. 14, E H will be still greater than in the case of a triangular wall of equal sectional area; and, if the wall were one solid mass incapable of fracture, this form would offer more resistance than the triangular. But, as this is not the case, we may consider any portion of the wall cut off from the bottom by a level line to be a distinct wall resting upon the lower part as a foundation. Imagine A *e* *b* to be a complete wall capable of turning upon *e* as a fulcrum. The resistance would be considerably less than that of the corresponding portion of a triangular wall. In the case of a triangular wall the proportions of the resistance to the thrust will be the same throughout its height. In the case of a rectangular one, the resistance will bear a greater proportion to the thrust the greater the distance from the bottom. In the case of a wall with a concave curved batter, the reverse of this takes place.

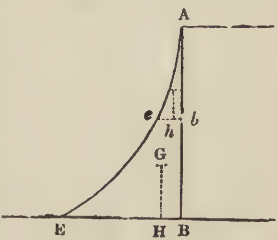


Fig. 14.

The value of E H will be greatest when E H = E B, the wall will be then exactly balanced on H; but in practice this limit should never be reached, for fear the wall should become crippled by depending on the earth for support. The value of E H will be least when H coincides with E, which opposite limit also is never reached in practice—for obvious reasons—as the wall would in this case overhang its base, and be on the point of falling forward.

36. The increased leverage is not the only advantage gained by the triangular form of wall. In the foregoing investigation we have considered the wall as a solid mass,

turning on its front edge. Now, practically, the difficulty is not so much to keep the wall from overturning as to prevent the courses from sliding on each other.

In an upright wall built in horizontal courses, the chief resistance to sliding arises from the adhesion of the mortar, but, if the wall be built with a sloping or *battering* face, the beds of the courses being inclined to the horizon, the resistance to the thrust of the bank is increased in proportion to the tendency of the courses to slide down towards the bank; thus rendering the adhesion of the mortar merely an additional security. The importance of making the resistance independent of the adhesion of the mortar is obviously very great, as it would otherwise be necessary to delay backing up a wall until the mortar were thoroughly set, which might require several months.

37. The exact determination of the thrust which will be exerted against a wall of given height is not possible in practice; because the thrust depends on the cohesion of the earth, the dryness of the material, the mode of backing up the wall, and other conditions which we have no means of ascertaining.

38. Experience has shown that the thickness of a vertical wall—that is, with both faces vertical—should not be less than one-third the height, at the base, when required to retain material loosely tipped. The back should be rough or stepped to increase the friction of the backing, thus adding to the stability. The batter on the face should not exceed one-sixth the height, to prevent the action of weather upon the face joints. The mortar for joints should be mixed with a portion of cement, or be made of cement mortar.

Walls with inclined faces and sloped or stepped backs, are to be made thicker at the base than vertical walls,

owing to the reduced section in the upper part of walls diminishing the weight, but not in proportion as the inclined face throws the centre of gravity further from the toe, increasing the leverage of overturning—and the line of pressure is directed more towards the toe, decreasing the leverage of pressure, the wall may thus be made lighter yet give the same stability as a vertical wall.

39. *Counterforts.*—Retaining walls are often built with counterforts, or buttresses, at short distances apart, which allow of the general section of the wall being made lighter than would otherwise be the case. The principle on which these counterforts are generally built is, however, very defective, as they are usually placed *behind* the wall, which frequently becomes torn from them by the pressure of the earth. The strength of any retaining wall would, however, be greatly increased were it built as a series of arches, abutting on long and thin buttresses ; but the loss of space that would attend this mode of construction has effectually prevented its adoption except in a few instances.

FACE OR BREAST WALLS.

40. Where the wall is required to prevent the falling away of earth from a vertical or inclined face, as in banks or railway cuttings, it is not usually necessary that the wall should be as thick as those previously described, as, owing to the natural formation being consolidated and undisturbed, the wall acts more as a face wall than to sustain the earth.

In constructing a wall of this kind the face of the earth (as soon as possible after the material has been removed) should be close planked and strutted, so as to protect against atmospheric influences and any movement of the earth taking place. After the wall is built the timbering

should be removed in sections, and the space closely packed with stones.

In ordinary cases a thickness of one-fourth—or less—the vertical height of wall will be found sufficient, depending, however, entirely upon the nature and formation of the strata.

41. The strength of a breast wall must be proportionately increased when the strata to be supported incline *towards* the wall, as in Fig. 15: where they incline from it,

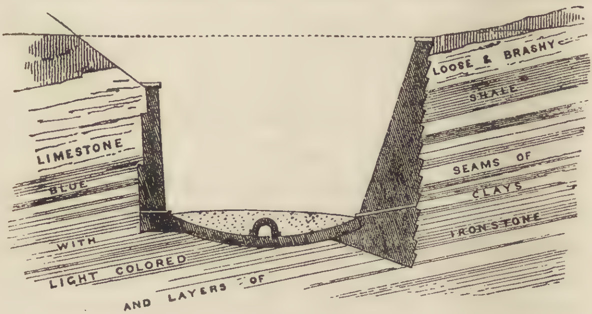


Fig. 15.

the wall need be little more than a thin facing to protect the ground from disintegration.

42. The preservation of the natural drainage is one of the most important points to be attended to in the erection of breast walls, as upon this their stability in a great measure depends. No rule can be given for the best manner of doing this; it must be a matter for attentive consideration in each particular case.

ARCHES.

43. An arch in perfect equilibrium may be considered as a slightly elastic curved beam, every part of which is in a

state of compression, the pressure arising from the weight of the arch and its superincumbent load being transmitted to the abutments on which it rests in a curved line called the *curve of equilibrium*, passing through the thickness of the arch.

44. The wedge-shaped stones of which a stone arch is composed are called the *voussoirs*. The upper surface of an arch is called its *extrados*, and the lower surface its *intrados* or *soffit* (see Fig. 16). Theoretically, a stone arch might give

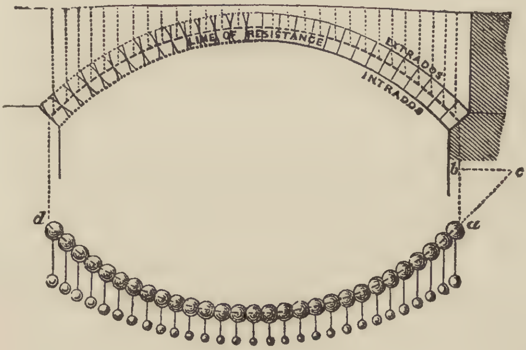


Fig. 16.

way by the sliding of the voussoirs on each other; but in practice the friction of the material and the adhesion of the mortar is sufficient to prevent this, and failure takes place in the case of an overloaded arch by the voussoirs turning on their edges.

45. The curve of equilibrium will vary with the rise and span of the arch, the depth of the arch stones, and the distribution of the load, but it will always have this property, namely, that the horizontal thrust will be the same at every part of it. In order that an arch may be in perfect

equilibrium, its curvature should coincide with that of the curve of equal horizontal thrust; if, from being improperly designed or unequally loaded, this latter curve approaches either the intrados or the extrados, the voussoirs will be liable to fracture from the pressure being thrown on a very small bearing surface; and if it be not contained within the thickness of the arch, failure will take place by the joints opening, and the voussoirs turning on their edges.

46. The manner in which the curve of equilibrium is affected by any alteration in the load placed upon an arch may readily be seen by making an experimental equilibrated arch with convex voussoirs, as shown in Fig. 16. When bearing its own weight only, the points of contact of the voussoirs will lie wholly in the centre of the thickness of the arch; when loaded at the crown, the points of contact will approach the extrados at the crown, and the intrados at the haunches; and, if loaded at the haunches, the reverse effect will take place.

47. If a chain be suspended at two points, and allowed to hang freely between them, the curve it takes is the curve of equilibrium of an arch of the same span and length on soffit, in which the weights of the voussoirs correspond to the weights of the links of the chain, and would be precisely the same as that marked out by the points of contact of the curved voussoirs of an experimental arch of the same dimensions built as above described.

48. In designing an arch, two methods of proceeding present themselves: we may either confine the load to the weight of the arch itself or nearly so, and suit the shape of the arch to a given curve of equilibrium, or we may design the arch as taste or circumstances may dictate, and load it until the line of resistance coincides with the curve thus determined upon.

The Gothic vaults of the Middle Ages were, in a great measure, constructed on the first of these methods, being in many cases only a few inches in thickness, and the curvature of the main ribs coinciding very nearly with their curves of equal horizontal thrust. We have no means of ascertaining whether this was the result of calculation or experiment; probably the latter, but the principle was evidently understood.

At the present day, the requirements of modern bridge building often leave the architect little room for choice in the proportions of his arches, or the height and inclinations of the roadway they are to carry; and it becomes necessary to calculate with care the proportion of the load which each part of the arch must sustain, in order that the curve of equilibrium may coincide with the curvature of the arch.

49. The formulæ for calculating the equilibrium of an arch are of too intricate a nature to be introduced in these pages; but the principles on which they depend are very simple.

Let it be required to construct a stone arch of a given curvature to support a level roadway, as shown in Fig. 16, and to find the weight with which each course of voussoirs must be loaded to bring the arch into equilibrium.

Draw the centre line of the arch to a tolerably large scale in an inverted position on a vertical plane, as a drawing board, for instance, and from its springing points, *a d*, suspend a fine silk thread of the length of the centre line strung with balls of diameter and weight corresponding to the thickness and weight of the voussoirs of the arch; then from the centre of each ball suspend such a weight as will bring the thread to the curve marked on the board, and these weights will represent the load which must be placed over the centre of gravity of each of the voussoirs, as shown

by the dotted lines, in order that the arch may be in equilibrium.

To find what will be the thrust at the abutments, or at any point in the arch, draw *a c*, touching the curve, the vertical line *a b* of any convenient length, and the horizontal line *b c*, then the lengths of the lines *a c*, *a b*, and *b c*, will be respectively as the thrust of the arch at *a*, in the direction *a c*, and the vertical pressure and horizontal thrust into which it is resolved; and the weight of that part of the arch between its centre and the point *a*, which is represented by *a b*, being known, the other forces are readily calculated from it.

50. When the form of an arch does not exactly coincide with its curve of equal horizontal thrust, there will always be some minimum thickness necessary to contain this curve, and to insure the stability of the arch. In a semicircular arch, Fig. 17, whose thickness is one-ninth of its radius, the line of equal horizontal thrust just touches the extrados at the crown, and the intrados at the haunches, pointing out the places where failure would take place, with a less thickness or an unequal load, by the voussoirs turning on their edges. Those arches which differ most from their curves of equal horizontal thrust are semicircles and semi-ellipses, which have a tendency to descend at their crowns and to rise at their haunches, unless they are well *backed up*. Pointed arches have a tendency to *rise* at the crown; and, to prevent this, the cross springers of the ribbed vaults of the Middle Ages were often made of a semicircular profile, their flatness at the crown being concealed by the bosses at their intersections.

51. If the experiment be tried of equilibrating, in the manner above described, a suspended semicircular or semi-elliptical arch, it will be found to be practically impossible,

as the weight required for that purpose becomes infinite at the springing. This difficulty does not exist in practice, for that part of an arch which lies beyond the plane of the

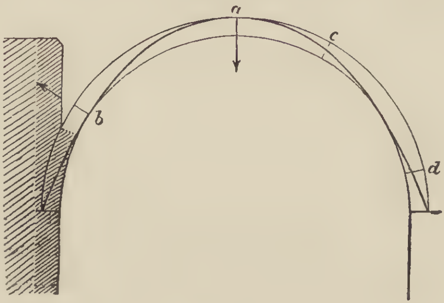


Fig. 17.

face of the abutment in reality forms a part of the abutment itself (Fig. 17).

The Gothic architects well understood this, and in their vaulted roofs built this portion in horizontal courses as part of the side walls (Fig. 18), commencing the real arch at a point considerably above the springing.

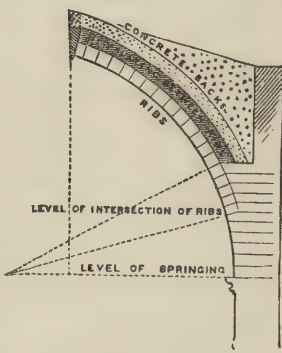


Fig. 18.

52. The depth of the voussoirs in any arch must be sufficient to contain the curve of equilibrium under the greatest load to which it can be exposed; and, as the pressure on the arch stones increases from the crown to the springing, their depth should be increased in the same proportion. Each joint of the voussoirs should be at

right angles to a tangent to the curve of equilibrium at the point through which it passes.

53. *Brick Arches.*—In building arches with bricks of the common shape, which are of the same thickness throughout their length, a difficulty arises from the thickness of the mortar joints at the extrados being greater than at the intrados, thus causing settlement and sometimes total failure. To obviate this difficulty, it is usual to build brick arches in separate rings of the thickness of half a brick, having no connection with each other beyond the adhesion of the mortar or cement, except an occasional course of headers where the joints of two rings happen to coincide. There is, however, a strong objection to this plan, viz., that if the curve of equal horizontal thrust do not coincide with the curvature of the arch, the line of pressure will cross the rings, and cause them to separate from each other.

54. The preferable plan will be, therefore, to bond the brickwork throughout the whole thickness of the arch, using either cement or hard-setting mortar, which will render the thickness of the joints of comparatively little importance.

A slow-setting Portland cement, however, should be always used in preference to the quick-setting quality, because the latter sets before the work can be completed, and in case of any settlement, however trifling, taking place on the striking of the centres, the work becomes crippled. A slow-setting cement mortar is ultimately of greater strength, and its slowness in setting allows the arch to adjust itself to its load, or, in technical language, to *take its bearing*, before the mortar becomes perfectly hard.

55. We have in the preceding remarks considered an equilibrated arch as a curved beam, every part of which is

in a state of compression; and, in an arch composed of stone voussoirs, this is practically the case.

We may, however, by the employment of other materials, as cast iron and timber, construct arches whose forms differ very materially from their curves of equal horizontal thrust.

Thus the semicircular arch (Fig. 17), which, if built of stone voussoirs small in proportion to the span of the arch, would fail by the opening of the joints at *a* and *b*, might be safely constructed with cast-iron ribs, with the joints placed at *c* and *d*, the metal at the points *a* and *b* being exposed to a cross strain precisely similar to that of a horizontal beam loaded in the centre.

56. Laminated arched beams, formed of planks bent round a mould to the required curve and bolted together, have been extensively used in railway bridges of large span during the last few years, and from their comparative elasticity, and the resistance they offer to both tension and compression, are very well adapted to structures of this kind, which have to sustain very heavy loads passing with great rapidity over them.

It is to be regretted, however, that the perishable nature of the material does not warrant their long duration, notwithstanding every precaution that can be taken for the preservation of the timber.

57. *Skew Arches.*—In ordinary cases the plan of an arch is rectangular, the faces of the abutments being at right angles to the fronts; but of late years the necessity which has arisen on railway works for carrying communications across each other without regard to the angle of their intersection has led to the construction of oblique or *skew* arches.

58. In an ordinary rectangular arch each course is

parallel to the abutments, and the inclination of any bed-joint with the horizon will be the same at every point of it. In a skew arch it is not possible to lay the courses parallel to the abutments, for, were this done, the thrust being at right angles to the direction of the courses, a great portion of the arch on each side would have nothing to keep it from falling. In order to bring the thrust into the right direction, the courses must therefore be laid as nearly as possible at right angles to the fronts of the arch (see Fig. 19), and at an angle with the abutments; and it is this which produces the peculiarity of the skew arch. The two ends of any course will then be at different heights, and the inclination of each bed-joint with the horizon will increase from the springing to the crown, causing the beds

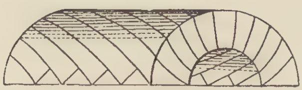


Fig. 19.

to be *winding* surfaces instead of a series of planes as in a rectangular arch. The variation of the inclination of the bed-joints is called the *twist* of the beds, and leads to many difficult problems in stone-cutting, the consideration of which would be unsuited to the elementary character of this litttle work.

The reader who wishes to pursue the subject is referred to the volume of this series "On Masonry and Stone-Cutting."

59. *Centering.*—The *centering* of an arch is the temporary framework which supports it during its erection, and is formed of a number of ribs or *centres*, on which are placed the planks or *laggings* on which the work is built.

60. In designing centres, there are three essential points

to be kept in view. 1st, that there should be sufficient strength to prevent any settlement or change of form during the erection of the arch. 2nd, that means should be provided for *easing* or lowering the centre gradually from under any part of the arch. 3rd, that, as the construction of centres generally involves the use of a large quantity of timber merely for a temporary purpose, all unnecessary

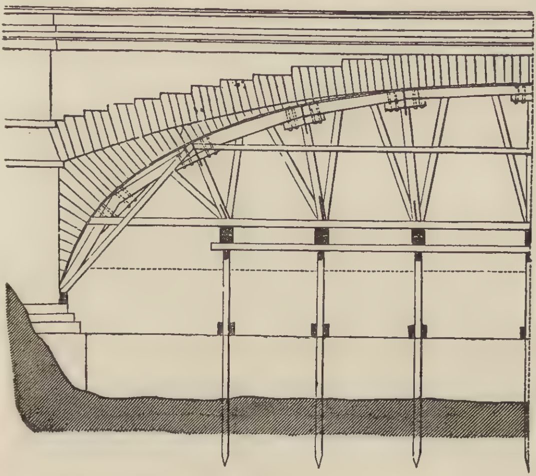


Fig. 20.

injury to it should be avoided, in order that its value for subsequent use may be as little diminished as possible.

61. Fig. 20 represents the construction of the centering used in the erection of the Gloucester Over Bridge, designed by Mr. Cargill, the contractor, which fulfils the above-named conditions in a very perfect manner : by means of the *striking wedges* under the radiating struts, any part of these centres can be lowered at pleasure, and, from the

position of the struts, there is no tendency to alteration in the curve from the undue pressure on the haunches during the erection of the arch.

62. Centering on the same principle as the above was made use of in the erection of the Grosvenor Bridge at Chester, by Mr. Trubshaw, the contractor for that work. Instead of the centres being made to rest on the striking wedges, however, as in the centering for the Gloucester Bridge, the wedges were placed under the laggings themselves, by which means the arch could be eased in the most gradual manner.

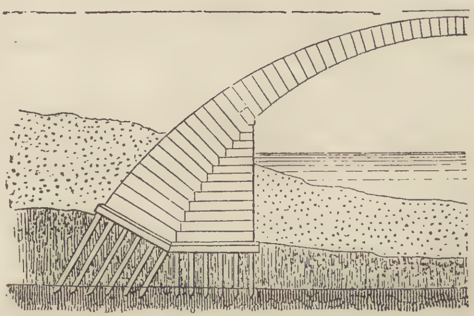


Fig. 21.

63. Where the circumstances of the case do not admit of piles or other supports being placed between the piers, it becomes necessary to construct a trussed framing resting on the piers, and of sufficient strength to support the weight of the arch. The tendency of this form of centre to rise at the crown, from the great pressure thrown upon the haunches during the erection of the arch, renders it necessary to weight the crowns with blocks of stone until it is nearly completed. Centres of this kind are always costly, afford less facilities for easing, and are in every way

inferior to those we have described as used at Gloucester and Chester.

64. *Abutments.*—The tendency of any arch to overturn its abutments, or to destroy them by causing the courses to slide over each other, may be counteracted in three ways, 1st, the arch may be continued through the abutment until it rests on a solid foundation, as in Fig. 21. 2nd, by building the abutments so as to form a horizontal arch, the thrust being thrown on the wing walls, which act as buttresses (Fig. 22). 3rd, where neither of these expedients is practicable, by joggling the courses together with bed-dowel joggles, so as to render the whole abutment one solid mass (Fig. 31).

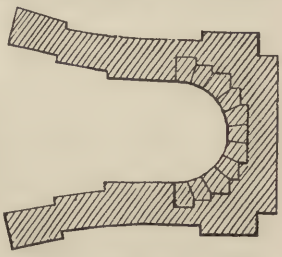


Fig. 22.

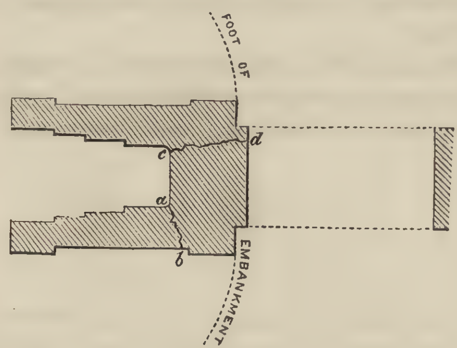


Fig. 23.

65. *Wing Walls.*—Where the wing walls of a bridge are built as shown in Fig. 23, the pressure of the earth will always have a tendency to fracture them at their junction

with the abutments, as shown by the lines *a b*, *c d*. Equal strength with the same amount of material will be obtained by building a number of thin longitudinal and cross walls, as shown in Fig. 24, by which means, the earth being kept

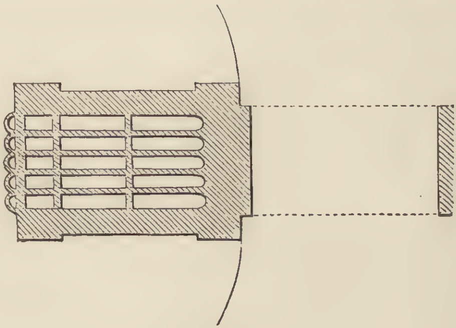


Fig. 24.

from the back of the walls, there is no tendency to failure of this kind.

66. *Vaulting.*—The ordinary forms of vaults may be classed under three heads: *cylindrical*, *coved*, and *groined*.

A *cylindrical* vault is simply a semicircular arch, the ends

Fig. 25.

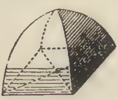


Fig. 26.

of which are closed by upright walls, as shown in Fig. 25. When a vault springs from all the sides of its plan, as in Fig. 26, it is said to be *coved*. When two cylindrical vaults intersect each other, as in Fig. 27, the intersections of the vaulting surfaces are called *groins*, and the vault is said to be *groined*.

67. In the Roman style of architecture, and in all common vaulting, the vaulting surfaces of the several compartments are portions of a continuous cylindrical surface, and the profile of a groin is simply an oblique section of a semi-cylinder.

68. Gothic ribbed vaulting is, however, constructed on a totally different principle. It consists of a framework of light stone ribs supporting thin panels, whence this mode of construction has obtained the name of *rib and pannel* vaulting. The curvature of the diagonal ribs or cross springers, and of the intermediate ribs, is not governed in

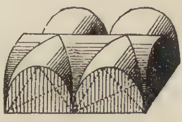


Fig. 27.—Roman Vaulting.

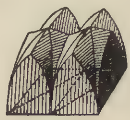


Fig. 28.—Gothic Vaulting.

any way by the form of the transverse section of the vault, and in this consists the peculiarity of ribbed vaulting. This will be understood by a comparison of Figs. 27 and 28. For a description of the several varieties of Gothic vaults, and the modes of tracing the curves of the ribs, the reader is referred to the volume of this series on "Masonry and Stone-cutting."

69. Domes are vaults on a circular plan. The equilibrium of a dome depends on the same conditions as that of a common arch, but with this difference, that, although a dome may give way by the weight of the crown forcing out the haunches, failure by the weight of the haunches squeezing up the crown is impossible, on account of the support the voussoirs of each course receive from each other.

MASONRY—BRICKWORK—BOND.

70. The term *masonry* is sometimes applied generally to all cemented constructions, whether built of brick or stone; but in England the use of the term is confined exclusively to stone-work.

71. There are many kinds of masonry, each of which is known by some technical term expressive of the manner in which the stone is worked; but they may all be divided under three heads.

Fig. 29.

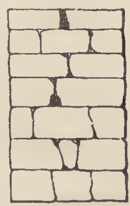


Fig. 30.

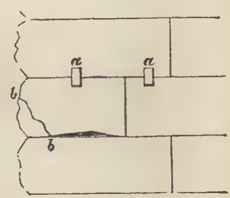


Fig. 31.

1st. Rubble work (Fig. 29), in which the stones are used without being squared.

2nd. Coursed work (Fig. 30), in which the stones are squared, more or less, sorted into sizes, and ranged in courses.

3rd. Ashlar work* (Fig. 31), in which each stone is squared and dressed to given dimensions.

72. Different kinds of masonry are often united. Thus a wall may be built with ashlar facing and rubble backing;

* In London the term "ashlar" is commonly applied to a thin facing of stone placed in front of brickwork in irregular courses not exceeding 10 inches high.

and there are many gradations from one class of masonry to another, as *coursed rubble*, which is an intermediate step between rubble work and coursed work.

73. In ashlar masonry, the stability of the work is independent, in ordinary cases, of the adhesion of the mortar. Rubble work, on the contrary, depends for support in a great measure upon it.

74. In dressing the beds of ashlar work, care must be taken not to work them hollow, so as to throw the pressure upon the edges of the stones, as this leads to unsightly fractures, as *b b*, Fig. 31.

75. Where there is a tendency of the courses to slide on each other from any lateral pressure, it may be prevented by bed-dowel joggles, as shown at *a a*, Fig. 31.

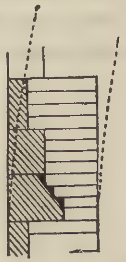


Fig. 32.

76. Where the facing and the backing of a wall do not contain the same number of courses, as in the case of a brick wall with stone facings (Fig. 32), the work will be liable to settle on the inside, as shown by the dotted lines, from the greater number of mortar joints. The only way of preventing this is to set the backing in cement, or some hard and quick-setting mortar.

77. In facing brickwork with stone ashlar, the stones should be all truly squared, and worked to sizes that will bond with the brickwork. If this be neglected, there will be numerous vacuities in the thickness of the wall (see Fig. 32), and the facing and backing will have a tendency to separate.

78. *Bond*, in masonry, consists in the placing of the stones in such relative positions that no joint in any course shall be in the same plane with any other joint in the course immediately above or below it. This is called *breaking joint*.

79. Stones placed lengthwise in any work are called *stretchers*, and those placed in a contrary direction are called *headers*. When a header extends throughout the whole thickness of a wall, it is called a *through*.

80. There are two kinds of bond made use of by bricklayers, called respectively *English bond* and *Flemish bond*. In the first the courses are laid alternately with headers and stretchers (Fig. 33); in the second, the headers and stretchers alternate in the same course (Fig. 34). This is considered to have the neatest appearance: but, as the number of headers required is fewer than in English bond, there is not so much lateral tie, and on this account it is considered to be much inferior to it in strength. A

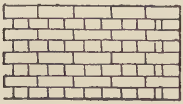


Fig. 33.

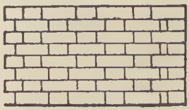


Fig. 34.

common practice, which cannot be too much reprobated, is that of building brick walls with two qualities of bricks, without any bond between them, the headers of the facing bricks being cut in two to save the better material, thus leaving an upright joint between the facing and backing.

81. In building upright walls which have to sustain a vertical pressure, three leading principles must be kept in view.

1. Uniformity of construction throughout the whole thickness.
2. The bonding of the work together.
3. The proper distribution of the load.

82. *Uniformity of Construction.*—We have already spoken

of the danger arising from the backing of a wall containing more compressible material than the facing; but it cannot be too often repeated, that in all building operations it is not the *amount*, but the *irregularity* of settlement which is so dangerous. Thus a rubble wall, with proper care, may be carried up to a great height, and bear safely the weight of the floors and roof of a large building, whilst a wall built of bricks and mortar, and faced with dressed ashlar, will, under similar circumstances, be fractured from top to bottom, from the difference in settlement of the facing and backing.

It is a common but vicious practice to build the ends of joists and other timbers into the walls, and to rest the superincumbent work upon them. This is liable to lead to settlements from the shrinking of the timber, and should always be guarded against by leaving proper recesses for the ends of the timbers, so that the strength of the masonry or brickwork shall be quite independent of any support from them.

83. *Bond.*—In addition to the bonding together of the materials above described, a further security against irregular settlement is usually provided for brick walls in the shape of ties of timber, called *bond*, which are cut of the depth and thickness of a brick, and built into the work. There is, however, a great objection to the use of timber in the construction of a wall, as it shrinks away from the rest of the work, and often endangers its stability by rotting.

84. Instead of bond timbers, hoop-iron bond is now very generally used. This is formed of iron hooping, tarred, to protect the iron from contact with the mortar, and laid in the thickness of the mortar joints. This forms a very perfect longitudinal tie, and has all the advantages, with none of the disadvantages, of bond timbers.

85. *Distribution of the Load.*—It is always advisable, when a heavy load has to be supported on a few points, as in the case of a large floor resting on girders, to bring the weight as nearly as possible on the centre of the wall, and to distribute it over a large bearing surface, by stone bonding through its whole thickness; this arrangement is shown in Figs. 35 and 36; and where a greater spread is required shallow and wide iron or steel girders are built into the wall, and the ends of the carrying girder rest on the centre of these girder wall plates. A suitable and strong bond, in which the brick or stone walls are built, should there distribute the weight over the whole wall.

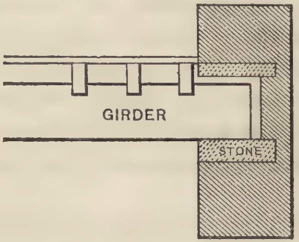


Fig. 35.

Fig. 36.

86. It is of importance in designing buildings to arrange the apertures for doors, windows, &c., in the different floors, so that openings shall be over openings, and piers over piers; if this be not attended to, it is scarcely possible to prevent settlements. In addition to this, as the pressure on the foundations will be greatest under the piers, it is desirable to connect these with inverted arches, by which means the weight is distributed equally over the whole surface of the foundations.

87. All openings in walls for doors, windows, gateways, &c., should be arched over throughout the whole thickness

of the walls in which they occur ; and wooden lintels and bressummers should only be introduced as ties to counteract the thrust of the arches, and as attachments for the internal finishings.

88. Bressummers of solid or flitched wood, or steel joists or compounds are used to support the main and other walls of buildings over large openings, such as shop windows, etc. Care should be taken that the piers supporting the ends of these bressummers are of sufficient sectional area and built with perfectly true beds in cement to carry the weights without causing settlements. In case of fire the solid wood beams will be found to cause least harm as they only char, and if large enough, leave a good solid baulk after the fire. The flitches will not be so good, as there is a greater surface to be charred, and the steel plate and bolts will buckle. The steel girders will be found to have suffered most, as under heat they expand, twist, and buckle, often causing the walls to collapse, and for this reason it is always advisable to encase or otherwise protect the steel against the flame.

PARTITIONS.

89. The partitions forming the interior divisions of a building may be either solid walling of brick or stone, or they may be constructed entirely of timber, or they may be frames of timber filled in with masonry or brickwork.

It will always be best, both for durability and security against fire, to make the partitions of solid walling ; though this is not always practicable, and, in the erection of dwelling houses, they are for the most part made of timber, but the cheapness and adaptability of iron or steel joists has rendered the employment of brick or stone solid walls more general in better class dwellings, for it is now very easy to

obtain girders to carry walls over any space, and consequently the modern architect is not so bound down to arrange his rooms so that the walls of upper rooms come immediately over those of the rooms below.

The principles to be kept in view in the construction of

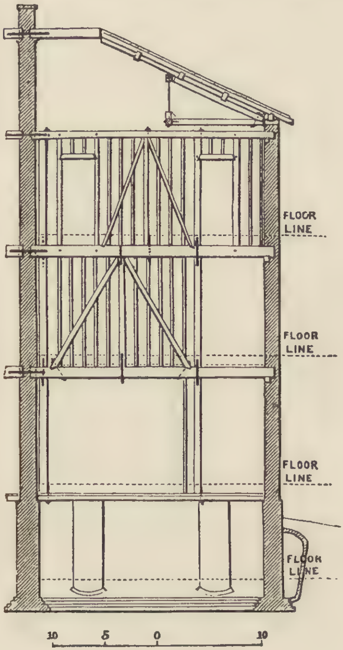


Fig. 37.

framed timber partitions are very simple. Care must be taken to avoid any settlement from cross strain, and they should not in any way depend for support upon subordinate parts of the construction, but should form a portion of the main carcase of the building, and be quite independent of

the floors, which should not support, but should be supported by them.

Where a partition extends through two or more stories of a building, it should be as much as possible a continuous piece of framing, with strong sills at proper heights to support the floor joists.

Where openings occur, as for folding doors, or where a partition rests on the ends of the sill only, it should be strongly trussed, so that it is as incapable of settlement as the walls themselves. From want of attention to these points, we frequently see in dwelling-houses floors which have sunk into curved lines, doors out of square, cracked ceilings and broken cornices, and gutters that only serve to conduct the roof water to the interior of the building, to the injury of ceilings and walls, and the great discomfort of its inmates. The above remarks will be better understood by a study of Fig. 37, which is an example of a framed partition extending through three stories of a dwelling-house.

FLOORS.

90. The assemblage of timbers forming any *naked flooring* may be either *single* or *double.* Single flooring is formed with joists reaching from wall to wall, where they rest on *plates* of timber built into the brickwork, as in Fig. 38. The floor boards are nailed over the upper edges of the joists, whose lower edges receive the lathing and plastering of the ceilings. Double floors are constructed with stout *binding ioists*, a few feet apart

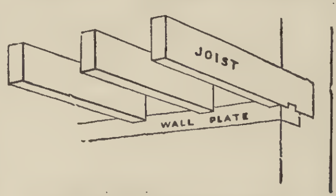


Fig. 38.—Single flooring.

reaching from wall to wall, and supporting *ceiling joists* which carry the ceiling; and *bridging joists*, on which are nailed the floor boards (Fig. 39.)

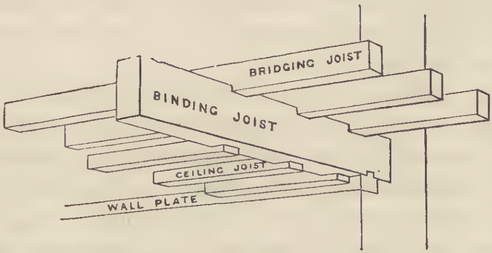


Fig. 39.—Double flooring.

In *double-framed flooring*, the binders, instead of resting in the walls, are supported on *girders*, as shown in Fig. 40.

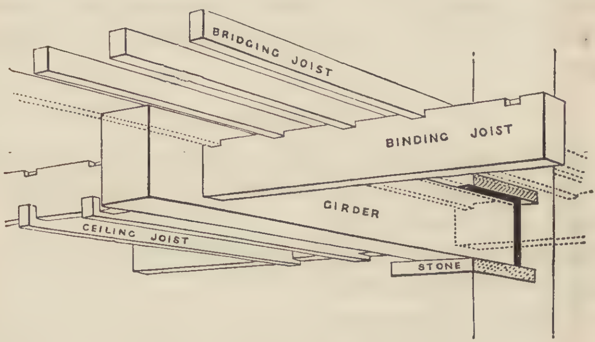


Fig. 40.—Double framed flooring.

Single flooring is, in many respects, inferior to double flooring, being liable to *sag*, or deflect, so as to make the floor concave, and the vibration of the joists occasions injury to the ceilings, and also shakes the walls. In double

flooring the stiffness of the binders and girders prevents both deflection and vibration, and the floors and ceilings *hold their lines*, that is, retain their intended form much better than in single flooring.

91. The joists in a single floor are usually laid on a plate built into the wall, as shown in Fig. 38; it is, however, preferable to rest the plate on projecting corbels, which pre-

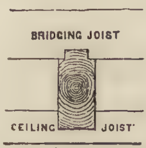


Fig. 41.

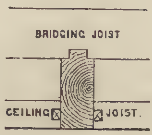


Fig. 42

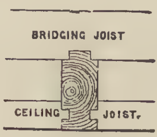


Fig. 43.

vents the wall being crippled in any way, by the insertion of the joists. The plates of basement floors are best supported on small piers carried up from the footings or on corbelling. This is an important point to be attended to, as the introduction of timber into a wall is nowhere likely to be productive of such injurious effects as at the foundations, where, from damp and imperfect ventilation, all wood-work is liable to speedy decay.

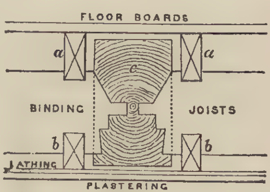


Fig. 44.
a a, bridging joists; *b b*, ceiling joists; *c*, girder.

The ends of all girders should rest in recesses, formed as shown in Figs. 35 and 36, and with a space for the free circulation of air round the timber, which is one of the best preventives of decay.

The manner in which ceiling joists and bridging joists are framed to the binders, and these latter tenoned into the girders, is shown in Figs. 41, 42, 43, and 44.

92. The scarcity of good timber and the adaptability, combined with increased strength at reasonable expense, of steel joists, has led to the substitution of steel joists in

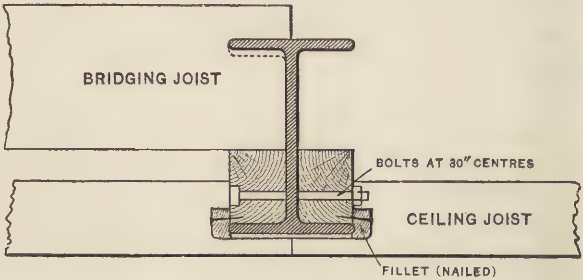


Fig. 45.

lieu of wood, double floors being treated as Fig. 45 and framed floors as Fig. 46.

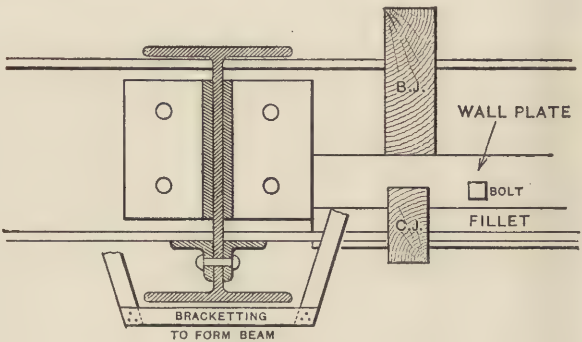


Fig. 46.

ROOFING.

93. In roofs of the ordinary construction, the roof covering is laid upon *rafters* supported by horizontal *purlins*, which rest on upright *trusses* or frames of timber, placed on the walls at regular distances from each other. Upon the framing of the trusses depends the stability of the roof, the arrangement of the rafters and purlins being subordinate matters of detail. The timbering of a roof may be compared to that of a double-framed floor, the trusses of the former corresponding to the girders of the latter, the purlins to the binders, and the rafters to the joists.

Timber roofs may be divided under (1st) Those which exert merely a vertical pressure on the walls on which they rest; (2nd) Those in which advantage is taken of the

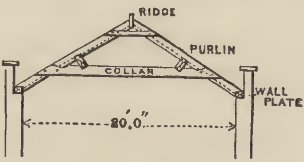


Fig. 47.

strength of the walls to resist a side thrust, as in many of the Gothic open timbered roofs.

94. *Trussed Roofs, exerting no Side Thrust on the Walls.*—In roofs of this kind each truss consists essentially of a pair of principal rafters or *principals*, and a horizontal *tie beam*, and in large roofs these are connected and strengthened by *king and queen posts* and *struts* (see Figs. 48, 49).

Fig. 47 shows a very simple truss in which the tie is above the bottom of the feet of the principals, which is often done in small roofs for the sake of obtaining height. The tie in this case is called a *collar*. The feet of both common and principal rafters rest on a *wall plate*. The

purlins rest on the collar, and the common rafters butt against a *ridge* running along the top of the roof. This kind of truss is only suited to very small spans, as there is a cross strain on that part of the principals below the collar which is rendered harmless in a small span by the extra strength of the principals, but which in a large one would be very likely to thrust out the walls.

95. In roofs of larger span the tie beam is placed below the feet of the principals, which are tenoned into, and bolted to it. To keep the beam from *sagging*, or bending by its own weight, it is suspended from the head of the

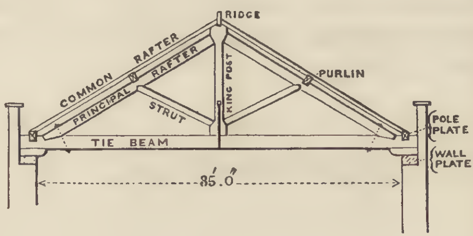


Fig. 48.

principals by a king post of wood or iron. The lower part of the king posts affords abutments for struts supporting the principals immediately under the purlins, so that no cross strain is exerted on any of the timbers in the truss, but they all act in the direction of their length, the principals and struts being subjected to compression, and the king post and tie beam to tension. Fig. 48 shows a sketch of a king truss. The common rafters butt on a *pole plate*, the tie beams resting either on a continuous plate, or on short templates of wood or stone.

96. Where the span is considerable, the tie beam is supported at additional points by suspension pieces called

queen posts (Fig. 49), from the bottom of which spring additional struts; and, by extending this principle *ad*

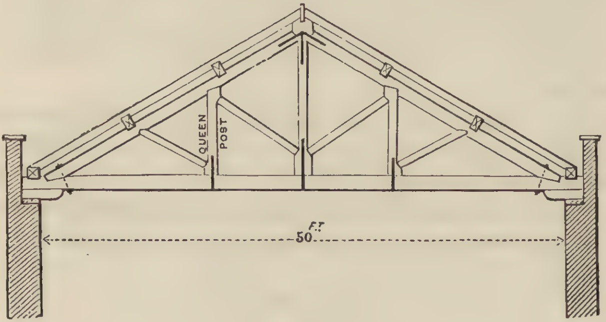


Fig. 49.

infinitum, we might construct a roof of any span, were it not that a practical limit is imposed by the nature of the materials. Sometimes roofs are constructed without

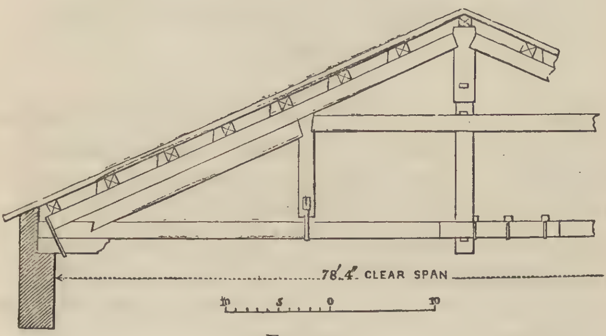


Fig. 50.

king posts, the queen posts being kept apart by a straining piece. This construction is shown in Fig. 50, which shows

the design of the old roof (now destroyed) of the church of St. Paul, outside the walls, at Rome. This truss is interesting from its early date, having been erected about 400 years ago; the trusses are in pairs, a king post being keyed in between each pair to support the tie beams in the centre.

97. Of late years iron and steel have quite superseded wood as a material for the trusses of large roofs, the tie beams and suspending pieces being formed of light rods or bars, and the principals and struts of rolled T or angle iron, to which sockets are riveted to receive the purlins.

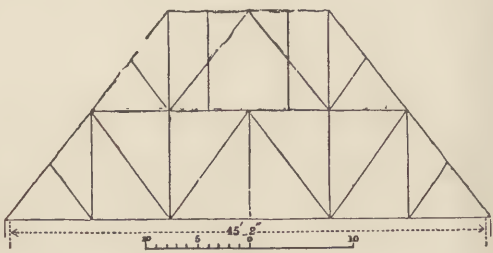


Fig. 51.

The iron roofs of the new Houses of Parliament at Westminster are admirable examples of this mode of construction. The principle of the trussing of the roof over the House of Peers is shown in Fig. 51. The tie beam and suspension rods are of flat bar iron, the principal and common rafters are of rolled T iron, the struts and purlins are of cast iron, and the whole is fitted together with cast-iron shoes.

98. The great novelty in the construction of the roofs just mentioned consist in their covering, which is formed of galvanized sheets of cast iron, lapping over each other

at the joints, and forming a very perfect and water-tight covering, which is at the same time perfectly fire-proof, and not liable to be affected by exposure to the atmosphere.

99. The largest roof ever executed in one span is that of

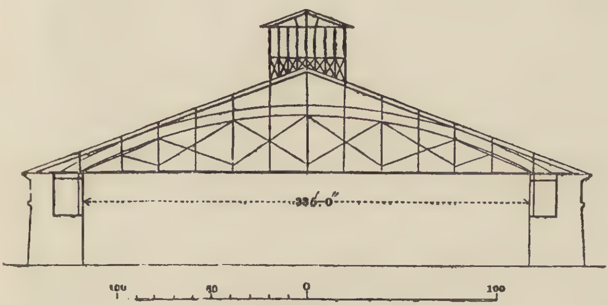


Fig. 52.

the Imperial Riding-House at Moscow, built in 1790, of which the span is 235 ft. (Fig. 52). The principal feature in this roof is an arched beam, the ends of which are kept from spreading by a tie beam, the two being firmly connected by suspension pieces and diagonal braces: the arched beam (Fig. 53) is formed of three thicknesses of

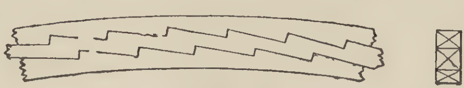


Fig. 53.

timber, notched out to prevent their sliding on each other, —a method which is objectionable on account of the danger of the splitting of the timber under a considerable strain.

100. The principle of the *bow suspension truss*, as this

system of trussing is called, has been much used within the last few years for railway bridges and similar works. One of the best executed works of this kind, is a bridge over the River Ouse, near Downham Market, in Norfolk, on the line of the Lynn and Ely Railway, the trusses of which are 120 ft. span.

101. *Roofs on the principle of the Arch.*—In the 16th century, Philibert de Lorme, a celebrated French architect, published a work in which he proposed to construct roofs and domes with a series of arched timber ribs in place of trusses, these ribs being formed of planks in short lengths, placed edgewise, and bolted together in thicknesses, breaking joint (Fig. 54). This mode of construction has been more or less used ever since the time of its author. An

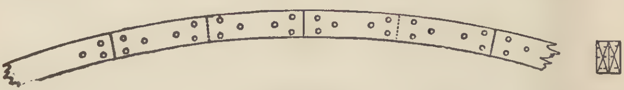


Fig. 54.

instance of its successful application on a large scale was the original dome of the Halle au Blé, at Paris, 120 feet in diameter, built by Messrs. Legrand and Molino. This roof has since been replaced by an iron one, the original dome having been destroyed by fire.

The roof of the central compartment of the Pantheon Bazaar in Oxford Street, London, 38 ft. span, is another very elegant example.

102. There are, however, some great disadvantages connected with this system. There is considerable waste of material; the labour is great as compared with roofs of similar span of the ordinary construction; and, as the chief strength of the rib depends upon the lateral cohesion of the fibres of the wood, it is necessary to provide such

an amount of surplus strength as shall insure it against the greatest cross strain to which it can be exposed from violent winds or otherwise.

103. Struck by these disadvantages, Colonel Emy, a French military engineer, proposed, in 1817, an improvement on the system of Philibert de Lorme, which was pre-

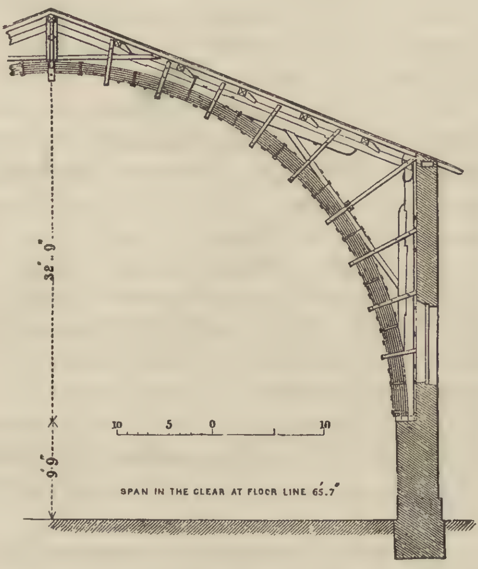


Fig. 55.

cisely the laminated arched rib so much in use at the present day. It was not until 1825 that he obtained permission to put his design into execution in the erection of a large roof 65 ft. span at Marac, near Bayonne (Fig 55). The ribs in this roof are formed of planks bent round on templets to the proper curve, and kept from separating

by iron straps, and also by the radiating struts which are in pairs, notched out so as to clip the rib between them.

The principle of the roof is exceedingly good. The principals, wall-posts, and arched rib, form two triangles, firmly braced together, and exerting no *thrust* on the walls; and the weight of the whole roof being thrown on the walls at the feet of the ribs, and not at the pole plate, the walls are not tried by the action of a heavy roof, and the consequent saving in masonry is very great.*

The great difference in principle between the arched rib of Philibert de Lorme, and the laminated rib of Colonel Emy, is, that in the latter the direction of the fibre of the wood coincides with the curvature of the rib; and, as a consequence of this, the joints are much fewer; the rib possesses considerable elasticity, so as slightly to yield rather than break under any violent strain; and, from the manner in which the planks are bolted together, it is impossible for the rib to give way, unless the force applied be sufficient to crush the fibres.

The principle of the laminated arched rib was first applied in England in 1837 by the Messrs. Green of Newcastle, by whom it has been extensively used in the erection of railway bridges.

104. *Gothic Roofs.*—The open timber roofs of the middle ages come, for the most part, under the second class, viz., those which exert more or less thrust upon the walls, although there are many fine examples in which this is not the case.

We propose to describe the principal varieties of these roofs, without reference either to their decorative details

* See Tredgold's "Carpentry," revised by E. Wyndham Tarn (Quarto: Crosby Lockwood & Son, London).

or to their chronological arrangement, our object here being simply to explain the principles on which they were constructed.

105. Fig 56, which is a section of the parish church of

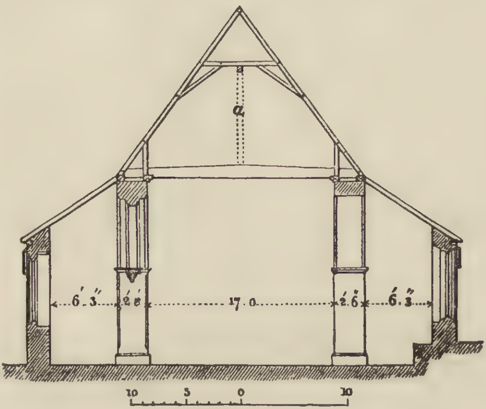


Fig. 56.

Chaldon, near Merstham in Surrey, shows a system of roofing formerly very common. This may be compared to single flooring, as there are no principals, purlins, or even ridge. It is a defective form of roof, as the rafters have a tendency to spread and thrust out the walls. In the example before us, this effect has been prevented by the insertion of tie beams, from which the collars have been propped up (Fig. 57), thus, in fact, balancing the roof on the centres of the collars, which are in consequence violently strained.

Fig. 57.
a, post; *b*, sill
c c, struts.

106. After the introduction of the 4-centred arch, a great

many church roofs of the construction just described were altered, as shown by the dotted lines in Fig. 58, in order to obtain more light by the introduction of clerestory windows over the nave arches. The flat roofs which superseded the former ones were often formed without any truss whatever, being simply an arrangement of main beams, purlins, and rafters, precisely similar to a double-framed floor, with the difference only that the main beams, instead of being perfectly straight, were usually cut out of crooked timber so as to divide the roof into two inclined planes.

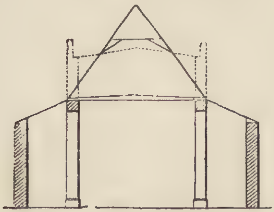


Fig. 58.

To throw the weight of the roof as low down as possible, the ends of the main beams are often supported on upright posts placed against the walls and resting on projecting corbels, the wall posts and beams being connected by struts in such a way that deflection in the centre of the beam cannot take place, unless the load be sufficient to force out the walls, as shown by the dotted lines in Fig. 59. The struts are often cut out of stout plank, forming solid spandrils, the edges of which are moulded to suit the profile of the main beam (see Fig. 60), which also shows the manner of securing the struts to the wall posts and to the beam with *tongues* and wooden pins. A very good example of this construction is shown in Fig. 61, which is from West Bridgeford Church, Nottinghamshire. There are many very beautiful examples remaining in different parts of the country.

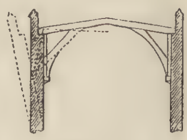


Fig. 59.

107. A somewhat similar construction to that last des-

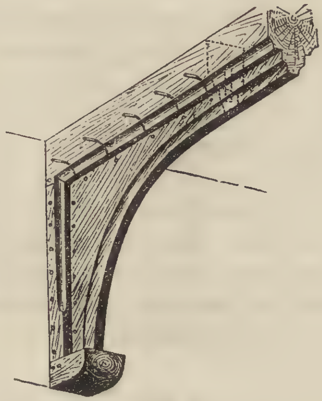


Fig. 60.

cribed is shown in Fig. 62, in which principals are intro-

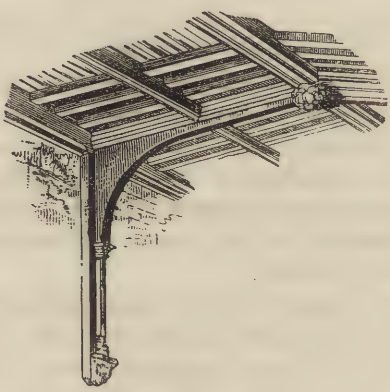


Fig. 61.

duced, strutted up from the main beam, so as to give a

greater slope to the roof than could well be obtained with a single beam.

108. Fig. 63 exhibits a construction often to be met with, which, in general appearance, resembles a trussed king post roof, but which is in reality very different, the tie beam being a strong girder supporting the king post, which, instead of serving to suspend the tie beam from the principals, is a prop to the latter. In this and the previous example, any tending to deflection of the tie beam is prevented by struts: the weight of the roof is thrown by means of wall posts considerably below the feet of the rafters, so that the weight of the upper part of the wall is made available to resist the thrust of the struts.

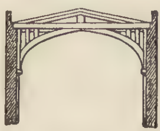


Fig. 62.

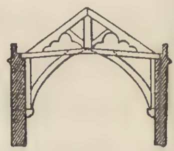


Fig. 63.

109. The roofs we have been describing are not to be recommended as displaying any great amount of constructive skill. Indeed, although they answer very well for small spans with timbers of large scantling and side walls of sufficient thickness to resist a considerable thrust, they are totally unsuited to large spans, and are in every way inferior to trussed roofs.

The above remarks do not apply to the high pitched roofs of the large halls of the fifteenth and sixteenth centuries, which, for the most part, are trussed in a very perfect manner, so as to exert no thrust upon the walls; although, in some instances, as at Westminster Hall, they depend upon the latter for support.

The general design of these roofs is shown in Figs. 64 and 65. The essential parts of each truss are, a pair of principals connected by a collar or *wind beam,* and two

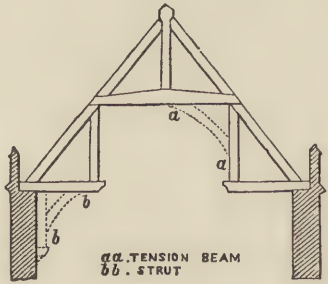


Fig. 64.

hammer beams, with queen posts over them, the whole forming three triangles, which, if not secured in their relative positions, otherwise than by the mere transverse strength of the principals, would turn on the points *c c*

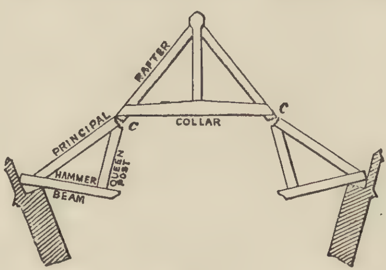


Fig. 65.

(Fig. 65), the weight of the roof thrusting out the walls in the manner shown in the figure. There are two ways in which a truss of this kind may be prevented from spreading.

1st. The ends of the hammer beams may be connected with the collar by tension pieces, *a a* (Fig. 64), by which the thrust on the walls will be converted into a vertical pressure. 2nd. The hammer beams may be kept in their places by struts, *b b*, the walls being made sufficiently strong by buttresses, or otherwise, to resist the thrust.

In existing examples, we find sometimes one and some-

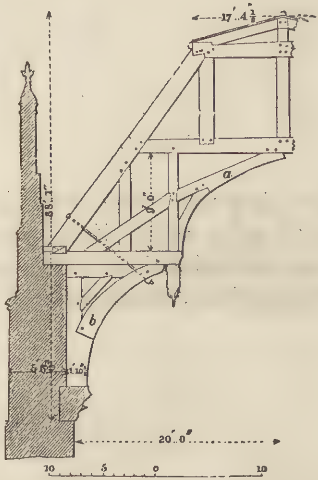


Fig. 66.

times the other of these plans followed; and occasionally both methods are combined in such a manner that it is often difficult to say what parts are in a state of compression, and what are in a state of tension.

110. The roof of the great hall at Hampton Court (Fig. 66) is very strong, and so securely tied, that were the bottom struts, *b b*, removed, there would be little danger of

the principals thrusting out the walls; and, on the other hand, from the weight of the roof being carried down to a considerable distance below the hammer beams by the wall posts, the walls themselves offer so much resistance to side thrust, that there would be no injurious strain on them were the tension pieces, *a a*, removed.

111. The construction of the roof of the hall at Eltham Palace, Kent (Fig. 67), differs very considerably from that

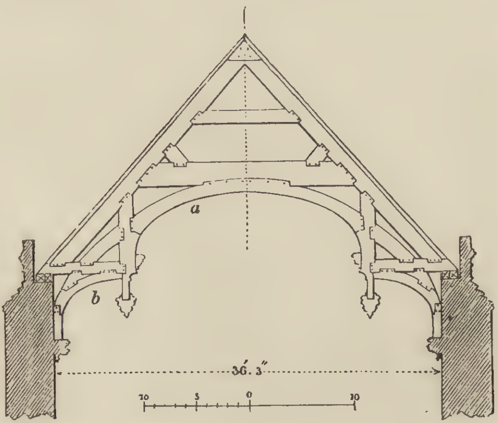


Fig. 67.

of the Hampton Court roof. The whole weight is thrown on the top of the wall, and the bottom pieces, *b b*, are merely ornamental, the tension pieces, *a a*, forming a complete tie. This has been shown by a partial failure which has taken place. The wall plates having become rotten in consequence of the gutters being stripped of their lead, the weight has been thrown on the pseudo struts, which have bent under the pressure, and forced out the upper portion of the walls.

112. The roof of Westminster Hall (Fig. 68) is one of the finest examples now existing of open timbered roofs.

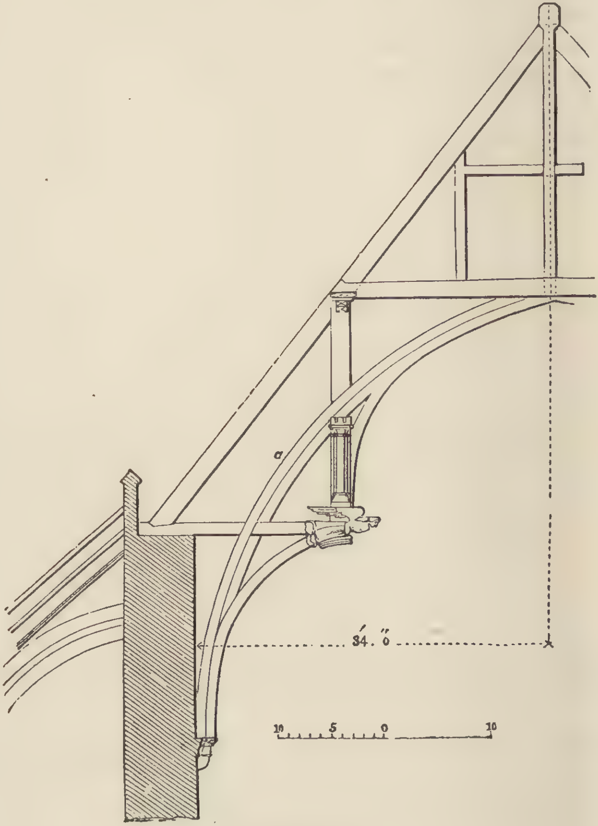


Fig. 68.

The peculiar feature of this roof is an arched rib in three thicknesses, something on the principle of Philibert de

Lorme; but it is so slight, compared with the great span, that it is probable in designing the roof the architect took full advantage of the support afforded by the thickness of the walls and the buttresses; if, indeed, the latter were not added at the time the present roof was erected, in 1395. It has been ascertained that the weight of the roof rests on the top of the walls, the lower part of the arched rib only serving to distribute the thrust, and to assist in preventing the hammer beams from sliding on the walls.

113. The mediæval architects generally employed oak in the construction of their large roofs, the timbers being morticed and pinned together, as shown in Fig. 60. This system of construction is impossible in fir and other soft woods, in which the fibres have little lateral cohesion, as the timber would split with the strain; and therefore, in modern practice, it is usual to secure the connections with iron straps or bolts passing round or through the whole thickness of the timbers.

ROOF COVERINGS.

114. The different varieties of roof coverings principally used may be classed under three heads: stone, wood, and metal.

Of the first class, the best kind is slate, which is used either sawn into slabs or split into thin laminæ. The different sizes of roofing slate in common use are given in the description of Slaters' Work, article 234.

In many parts of the country thin slabs of stone are used in the same way as roofing slate. In the Weald of Sussex the stone found in the locality is much used for this purpose, but it makes a heavy covering, and requires strong timbers to support it.

115. *Tiles* are of two kinds: *plain tiles,* which are quite

flat; and *pantiles*, which are of a curved shape, and lap over each other at the sides. Each tile has a projecting ear on its upper edge, by which it is kept in its place. Sometimes plain tiles are pierced with two holes, through which oak pins are thrust for the same purpose.

116. Wooden coverings are little used at the present day, except for temporary purposes; *shingles* of split oak were formerly much used, and may still be seen on the roofs of some country churches.

117. *Metallic Coverings.*—The metals used for roof coverings are lead, zinc, copper, and iron.

118. Lead is one of the most valuable materials for this purpose on account of its malleability and durability, the action of the atmosphere having no injurious effect upon it. Lead is used for covering roofs in sheets weighing from 4 to 8 lbs. per sup. foot.

119. Copper is used for covering roofs in thin sheets weighing about 16 oz. per sup. foot, and from its lightness and hardness has some advantages over lead; but the expense of the metal effectually precludes its general adoption.

120. Zinc has of late years superseded both lead and copper to a considerable extent as roof coverings. It is used in sheets weighing from 12 oz. to 20 oz. per sup. foot. It is considered an inferior material to those just named; but its lightness and cheapness are great recommendations, and the manufacture has been much improved since its first introduction.

121. Asphalte, a mastic bitumenous limestone, is much used for coverings to flat roofs and verandahs; it can be applied on a cement screed on concrete, or on felt laid on boarding, and it is a valuable material, as it is said to be frost and fire proof, in addition to damp proof. Vulcanite is a substitute for asphalte.

122. All metallic coverings are subject to contraction and expansion with the changes of the temperature, and great care is requisite in joining the sheets to make them lap over each other, so as to make the joints water-tight, without preventing the play of the metal. Tiles are non-conductors of heat and cold, and slates have the opposite effect.

The following table of the comparative weights of different roof coverings may be useful :—

	Cwts.	qrs.	lbs.
Plain tiles, per square of 100 ft. sup. . .	18	0	0
Pantiles	9	2	0
Slating, an average	7	0	0
Lead, 7 lb. to the sup. foot	6	2	0
Copper or zinc, 16 oz. do.	1	0	0

SUPPLY OF WATER.

123. The arrangements for distributing a supply of water over the different parts of a building will depend very materially on the nature of the supply, whether constant or intermittent.

The most common method of supply from water-works is by pipes which communicate with private cisterns, into which the water is turned at stated intervals.

A cistern, in a dwelling-house, is always more or less an evil; it takes up a great deal of space, costs a great deal of money in the first instance, and often causes inconvenience, from leakage, from the bursting of the service pipes in frosty weather, and from the liability of the self-acting cock to get out of order.

Fig. 69 shows the ordinary arrangements of a cistern for a dwelling-house. The common material for the cistern itself is galvanized wrought-iron or wood lined with sheet

lead; but slate cisterns are also used. Large cisterns or tanks for the supply of breweries, manufactories, &c., are usually made of cast-iron plates, screwed together by means of flanges all round their edges.

The service or feed pipe for a cistern, in the case of an intermittent supply, must be sufficiently large to allow of its filling during the time the water is turned on from the mains. The flow of water into the cistern is regulated by a *ball cock*, so called from its being opened and shut by a lever, with a copper ball, which floats on the surface of the water.

The service pipes to the different parts of the building are laid into the bottom of the cistern, but should not come within an inch of the actual bottom, in order that the sediment, which is always deposited in a greater or less degree, may not be disturbed: the mouth of each pipe should be covered by a *rose*, to prevent any foreign substances being washed into the pipes and choking the taps.

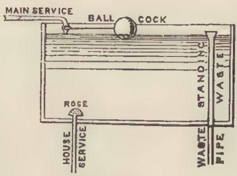


Fig. 69.

To afford a ready means of cleaning out the cistern, a waste pipe is inserted quite at the bottom, sufficiently large to draw off the whole contents in a short time when required; into this waste pipe is fitted a *standing waste*, which reaches nearly to the top of the cistern, and carries off the waste water, when, from any derangement in the working of the ball cock, the water continues running after the cistern is full. To prevent any leakage at the bottom of the standing waste, the latter terminates in a brass plug, which is ground to fit a washer inserted at the top of the waste pipe.

Where the supply of water is *constant*, instead of being

intermittent, private cisterns may be altogether dispensed with; the main service pipes, not being required to discharge a large quantity of water in a short time, may be of smaller bore, and consequently cheaper, and a considerable length of pipe is saved, as the water can be laid on directly to the several taps, instead of having to be taken up to the cistern and then brought back again. The constant flow of water through the pipes also much diminishes the risk of their bursting in frosty weather from freezing of their contents.

WARMING AND VENTILATION.

124. The various contrivances employed for warming buildings may be classed as under :—

Methods of Warming independently of Ventilation.

125. 1st. Separate open fires or stoves in every room with their own flues, etc. These are pleasant to the eye, and may be decorated according to requirements, while they are under separate control, and entail comparatively little expense. They should be fixed low down to prevent draught affecting the occupants' feet, and to keep down the rapidity of combustion, and they should have as much fire-brick and as little iron about them as possible, for the fire-brick retains heat. The fire should be placed forward in the fireplace instead of in recess, so that the heat comes into the room instead of passing up the chimney.

126. 2nd. Systems of continuous piping filled with steam or hot water on the high or low pressure principles, worked from one fire, and controlled at various points. The objections to hot water systems of heating are the unsightliness and inconvenience of the coils and piping in the rooms—the low pressure system of pipes of larger diameter being more

open to objection than the smaller pipes with coils as used on the high pressure principle. On the other hand the risk of explosion is greater on the latter than the low pressure.

Methods of Warming combined with Ventilation.

127. 3rd. By the "Plenum" system, which consists of collecting at certain points the best external air, drawing it by means of fans driven by steam or electricity into large flues or ducts, generally underground. During the course of its entrance this air is cleansed, warmed, or cooled and humidified, and then passed under slight pressure through branch flues into the rooms, etc. Care must be taken that the flues are free from any possibility of becoming contaminated. The pure air required is brought in at a level of about 8 feet from the floor, and the foul air is drawn out at the floor level into trunks which carry it away at the roof, or other ventilators. It should be understood that the warm air being lighter ascends and distributes itself, while the cold air falls, and if the means of lighting the rooms has the effect of vitiating the air, then the result will be that foul air is breathed by the occupants, but such would not happen if electric light were the means of illumination, so that the latter is necessary to render the Plenum system absolutely successful. The air may be regulated and changed or renewed up to fifteen times an hour, and it is acknowledged that each person requires 1,500 to 1,800 cubic feet per hour, so that it is only a matter of arithmetic to calculate the sizes of flues in conjunction with the velocity, which should not exceed more than three or four feet per second to avoid draughts. The temperature of a room should be maintained in winter and summer at from 55 to 65 degrees Fahr., to be the ideal of comfort.

There are several systems of warming rooms by passing air heated to perhaps 120 degrees Fahr. into them to mix with the cold, the inlet and outlet both being at the floor line, but the air does not always get evenly distributed, and objections are general on that account unless means are taken to equalize the temperature, and prevent the stagnation of areas of foul, hot, or cold air.

Rooms can also be heated and ventilated by systems whereby hot air is brought in at the floor level and extracted at the ceiling—a quite natural process, but open to objections similar to the last. It will be gathered that most of these systems can only be employed where the buildings are designed to receive them. It is only in exceptional cases where they can be adapted to old buildings.

In all methods of warming, in which the air is heated by coming in contact with metallic heating surfaces, care should be taken that their temperature should not exceed 212°, as when this limit is exceeded, the air becomes unfit for use, and offensive from the scorching of the particles of dust or other matters that are always floating in it.

SECTION

MATERIALS USED IN BUILDING.

128. The materials used in building may be classed under the heads TIMBER, STONE, SLATE, BRICKS AND TILES, LIMES AND CEMENTS, METALS, GLASS, COLOURS AND VARNISHES. Of these, Slate and Glass will be found noticed in Section IV. of this volume (pp. 129 and 143); and our remarks in this section will be confined to the consideration of Timber, Limes and Cements, and Metals. Those desirous of further investigation of those subjects, or of pursuing the study of the other materials referred to, will do well to consult the Publishers' list inserted at the end of this volume.

TIMBER.

129. If we examine a transverse section of the stem of a tree, we perceive it to consist of three distinct parts: the *bark*, the *wood*, and the *pith*. The wood appears disposed in rings round the pith, the outer rings being softer and containing more sap than those immediately round the pith which form what is called the *heart wood*.

These rings are also traversed by rays extending from the centre of the stem to the bark, called *medullary rays*.

The whole structure of a tree consists of minute vessels and cells, the former conveying the sap through the wood in its ascent, and through the bark to the leaves in its descent; and the latter performing the functions of secretion and nutrition during the life of the tree. The solid parts of a tree consist almost entirely of the fibrous parts composing the sides of the vessels and cells.

By numerous experiments it has been ascertained that the sap begins to ascend in the spring of the year, through the minute vessels in the wood, and descends through the bark to the leaves, and, after passing through them, is deposited in an altered state between the bark and the last year's wood, forming a new layer of bark and sapwood, the old bark being pushed forward.

As the annual layers increase in number, the sapwood ceases to perform its original functions; the fluid parts are evaporated or absorbed by the new wood, and, the sides of the vessels being pressed together by the growth of the latter, the sapwood becomes heartwood or perfect wood, and until this change takes place it is unfit for the purposes of the builder.

The vessels in each layer of wood are largest on the side nearest the centre of the stem, and smallest at the outside. This arises from the first being formed in the spring, when vegetation is most active. The oblong cells which surround the vessels are filled with fluids in the early growth; but as the tree increases in size these become evaporated and absorbed, and the cells become partly filled with depositions of woody matter and indurated secretions, depending on the nature of the soil, and affecting the quality of the timber. Thus Honduras mahogany is full of black specks, while the Spanish is full of minute white particles, giving the wood the appearance of having been rubbed over with

chalk. At a meeting of the Institution of Civil Engineers, March, 1842, it was stated by Professor Brande that "a beech tree in Sir John Sebright's park in Hertfordshire, on being cut down, was found perfectly black all up the heart. On examination it was discovered that the tree had grown upon a mass of iron scoriæ from an ancient furnace, and that the wood had absorbed the salt of iron." This anecdote well explains the differences that exist between different specimens of the same kind of timber under different circumstances of growth: and it is probably the nature of the soil that causes the difference of character we have just named between Honduras and Spanish mahogany.

There is a great difference in the character of the annual rings in different kinds of trees. In some they are very distinct, the side next the heart being porous, and the other compact and hard, as in the oak, the ash, and the elm. In others the distinction between the rings is so small as scarcely to be distinguished, and the texture of the wood is nearly uniform, as in the beech and mahogany. A third class of trees have the annual rings very distinct and their pores filled with resinous matter, one part being hard and heavy, the other soft and light-coloured. All the resinous woods have this character, as larch, fir, pine, and cedar.

The medullary rings are scarcely perceptible to the naked eye in the majority of trees; but in some, as the oak and the beech, there are both large and small rings, which, when cut through obliquely, produce the beautiful flowered appearance called the silver grain.

130. In preparing timber for the uses of the builder there are three principal things to be attended to, viz., the age of the tree, the time of felling, and the seasoning for use.

131. If a tree be felled before it is of full age, whilst the heartwood is scarcely perfected, the timber will be of inferior quality, and, from the quantity of sap contained in it, will be very liable to decay. On the other hand, if the tree be allowed to stand until the heartwood begins to decay, the timber will be weak and brittle: the best timber comes from trees that have nearly done growing, as there is then but little sapwood, and the heartwood is in the best condition.

132. The best time for felling trees is either in midwinter, when the sap has ceased to flow, or in midsummer, when the sap is temporarily expended in the production of leaves. An excellent plan is to bark the timber in the spring and fell it in winter, by which means the sapwood is dried up and hardened: but as the bark of most trees is valueless, the oak tree (whose bark is used in tanning) is almost the only one that will pay for being thus treated.

133. The seasoning of timber consists in the extraction or evaporation of the fluid parts, which are liable to decomposition on the cessation of the growth of the tree. This is usually effected by steeping the green timber in water, to dilute and wash out the sap as much as possible, and then drying it thoroughly by exposure to the air in an airy situation. The time required to season timber thoroughly in this manner will of course much depend on the sizes of the pieces to be seasoned; but for general purposes of carpentry, two years is the least that can be allowed, and, in seasoning timber for the use of the joiner, a much longer time is usually required.

134. *Decay of Timber.*—Properly seasoned timber, placed in a dry situation with a free circulation of air round it, is very durable, and has been known to last for several hundred years without apparent deterioration. This is not,

however, the case when exposed to moisture, which is always more or less prejudicial to its durability.

When timber is constantly under water, the action of the water dissolves a portion of its substance, which is made apparent by its becoming covered with a coat of slime. If it be exposed to alternations of dryness and moisture, as in the case of piles in tidal waters, the dissolved parts being continually removed by evaporation and the action of the water, new surfaces are exposed, and the wood rapidly decays.

Where timber is exposed to heat and moisture, the albumen or gelatinous matter in the sapwood speedily putrefies and decomposes, causing what is called rot. The rot in timber is commonly divided into two kinds, the *wet* and the *dry*, but the chief difference between them is, that where the timber is exposed to the air, the gaseous products are freely evaporated; whilst, in a confined situation, they combine in a new form, viz., the dry-rot fungus, which, deriving its nourishment from the decaying timber, often grows to a length of many feet, spreading in every direction, and insinuating its delicate fibres even through the joints of brick walls.

In addition to the sources of decay above mentioned, timber placed in sea water is very liable to be completely destroyed by the perforations of the worm, unless protected by copper sheathing, the expense of which causes it to be seldom used for this purpose.

135. *Prevention of Decay.*—The best method of protecting woodwork from decay when exposed to the weather is to paint it thoroughly, so as to prevent its being affected by moisture. It is, however, most important not to apply paint to any woodwork which has not been thoroughly seasoned; for in this case, the evaporation of the sap being prevented, it decomposes, and the wood rapidly decays.

Many plans have been proposed for the prevention of rot, but very often the processes confer a disadvantage while doing good; for instance, creosoting renders wood more inflammable and, furthermore, you can neither paint nor whitewash it, it must remain its dirty colour.

The best known systems are as follows:—

Creosoting, discovered by Bethell, consists of thoroughly saturating the wood with oil of creosote by forcing the oil in under pressure.

Kyanizing consists of impregnating the timber with corrosive sublimate, thus converting the albumen into an indecomposable substance, at the same time this renders the wood almost non-inflammable.

Burnettizing is a process by which the wood is soaked in chloride of zinc, an operation which does not discolour the wood.

Boucherie's method is to pour sulphate of copper into the top of the log and let it soak right through to the bottom.

Haskenizing consists of placing the wood in large cylinders and forcing air at a heat of 300° to 400° Fahr. through its pores to dry up the sap and render it antiseptic and able to resist wet or dry rot.

Charring the exterior of wood to be placed in the ground is also a valuable preventative against rot.

136. The variety of timber trees suitable to the purposes of the builder is very great; but fir and oak are the kinds chiefly used, although larch, beech, poplar and other woods, are employed to a limited extent in localities where they can be obtained more cheaply than foreign timber. Very little home-grown fir is used in England, as foreign timber, either in balks, or cut up into planks, deals, or battens, can be obtained at a moderate price in all the large towns in

the kingdom, and is very superior to any grown in this country. Baltic timber is more esteemed than American, but a very great deal of the latter is used.

137. Fir is one of the most useful of the woods used by the builder. It is light, soft, easily worked, and very durable; but the lateral cohesion of the annual rings being very slight, it will not bear much strain, except in the direction of the length of the fibres. Red pine is also much used for carpenters' and external joiners' work, and is very durable. Whitewood, having very little strength, is only used internally and for an inferior class of work.

Yellow pine is much used for internal work of the best quality. Pitch pine is very resinous, is imported from the Southern States of North America, and is much used for internal joinery and in logs where Baltic pine cannot be procured.

138. Oak is grown in England, and imported from America, Germany and Austria. The English oak has the greatest strength and durability, but it is getting scarce, American oak replacing it (but only on account of its price and plentifulness) for use under conditions where strength and durability are in the ascendant. The oak from Stettin also shares the supply of a similar demand, but the wainscot quality imported from the German Baltic ports and ports of the Adriatic (and from America as well) is a wood of a kind nature, easy to work and of fine figure or flower, suitable for the best internal finishings.

139. Mahogany is much used for internal finishings, being imported from Central America (Honduras), the West Indies and Central Africa; Spanish mahogany (from Cuba) is the hardest and best, being richest in colour, but it is becoming very scarce.

Walnut is of a mauve brown colour, imported from North

America, and suitable for internal work of the best kind; it will take a high polish just like oak, mahogany, or teak.

Teak is yellow-brown in colour, imported from Burmah and the East Indies, and suitable for the best joinery.

LIMES AND CEMENTS, MORTAR, ETC.

140. So much of the stability of brickwork and masonry depends upon the binding properties of the mortar or cement with which the materials are united, especially when exposed to a side pressure, as in the case of retaining walls, arches, and piers, that it is of no small importance to ascertain on what the strength of mortar really depends, and how far the proportions of the ingredients require modification, according to the quality of the lime that may have to be used.

It was long supposed that the hardness of any mortar depended upon the hardness of the limestone, from which the lime used in its composition was derived; but it was ascertained by the celebrated Smeaton, and since his time clearly shown by the researches of others, amongst whom may be named, Vicat in France, and Lieutenant-General Sir Charles Pasley in this country, that the hardness of the limestone has nothing to do with the matter, and that it is its chemical composition which regulates the quality of the mortar.

141. Limestone may be divided into three classes.

1st. Pure limes—as chalk.

2nd. Water limes—some of which are only slightly hydraulic, as the stone limes of the lower chalk, whilst others are eminently so, as the lias limes.

3rd. Water cements—as those of Sheppy and Harwich.

142. In making mortar the following processes are gone through.

1st. The limestone is calcined by exposure to strong heat in a kiln, which drives off the carbonic acid gas contained in it, and reduces it to the state of *quick-lime.*

2nd. The quick-lime is *slaked* by pouring water upon it, when it swells, more or less, with considerable heat, and falls into a fine powder, forming a *hydrate* of lime.

3rd. The hydrate thus formed is mixed up into a stiffish paste, with the addition of more water, and a proper proportion of sand, and is then ready for use.

143. *Pure Limes.—Chalk* is a pure carbonate of lime, consisting of about 5 parts of lime combined with 4 of carbonic acid gas. It expands greatly in slaking, and will bear from 3 to 3½ parts of sand to one of lime, when made up into mortar. Chalk lime mortar is, however, of little value, as it *sets* or hardens very slowly, and in moist situations never sets at all, but remains in a pulpy state, which renders it quite unfit for any work subjected to the action of water, or even for the external walls of a building.

144. Gypsum, from which is made *plaster of Paris* for cornices and internal decorations, is granular sulphate of lime, and contains 26·5 of lime, 37·5 of sulphuric acid, and 17 of water. It slakes without swelling, with a moderate heat, setting hard in a very short time, and will even set under water; but as it is, like other pure limes, partly soluble in water, it is not suitable for anything but internal work.

145. *Water limes* have obtained their name from the property they possess in a greater or less degree of setting under water. They are composed of carbonate of lime, mixed with silica, alumina, oxide of iron, and sometimes other substances.

146. *Dorking lime*, obtained from the beds of the lower chalk, at Dorking, in Surrey; and *Halling lime*, from a

similar situation near Rochester, in Kent, are the principal limes used in London for making mortar, and are slightly hydraulic; they expand considerably in slaking, but not so much as the pure limes, and will make excellent mortar when mixed with 3 parts of sand to one of lime. Mortar made with these limes sets hard and moderately quick, and *when set*, may be exposed to considerable moisture without injury; but they will not set under water, and are therefore unfit for hydraulic works, unless combined with some other subtance, as *puzzolana*, to give them water-setting properties.

147. The *blue lias limes* are the strongest water limes in this country. They slake very slowly, swelling but little in the process, and set very rapidly even under water; a few days only sufficing to make the mortar extremely hard. The lias limes will take a much smaller proportion of sand than the pure limes, the reason of which will be understood when it is remembered that they contain a considerable proportion of silica and alumina, combined with the lime in their natural state, and consequently the proportion of sand which makes good mortar with chalk lime, would ruin mortar made with Aberthaw, Watchet, Barrow, and other lias limes.

In the Vale of Belvoir, where the lias lime is extensively used, the common practice is to use equal parts of lime and sand for inside work, and one-half sand to one of lime for face work.

148. *Water Cements.*—These differ from the water-limes, as regards their chemical composition, only in containing less of carbonate of lime and more of silica and alumina. They require to be reduced to a fine powder after calcination, without which preparation they cannot be made to slake. The process of slaking is not accompanied by any

increase of bulk, and they set under water in a short time, a few hours sufficing for a cement joint to become perfectly hard.

The principal supplies of cement-stone for the London market are derived from Harwich in Essex, and the Isle of Sheppey in Kent; where they are found in the London clay in the form of calcareous nodules.

A good Portland cement, whether natural or artificial, should be in such proportions, that in the calcination the silica and alumina should take up all the lime and form silicate and aluminate of lime.

149. The use of natural cement was introduced by Mr. Parker, who first discovered the properties of the cement-stone in the Isle of Sheppey, and took out a patent for the sale of it in 1796, under the name of Roman cement.

Before that time, hydraulic mortar, for dock walls, harbour work, &c., was usually made by mixing common lime with trass, from Andernach in Germany, or with puzzolana from Italy; both are considered to be volcanic products, the latter containing silica and alumina, with a small quantity of lime, potash, and magnesia. Iron is also associated with it in a magnetic state.

150. The expense of natural puzzolana led to the manufacture of artificial puzzolana, which appears to have been used at an early date by the Romans, and has continued in use in the South of Europe to the present day; artificial puzzolana is made of pounded bricks or tile dust. The Dutch manufacture an artificial puzzolana from burnt clay, an imitation of the trass of Andernach, which is said to be a close imitation of the natural product.

151. The great and increasing demand for cement, and its great superiority for most purposes over lime mortar, have induced manufacturers to turn their attention to the

manufacture of artificial cement, and this has been attended in many instances with perfect success; the artificial cements now offered for sale as Portland cement, formed by imitating the composition of the natural cement-stones, being superior in quality to the Roman cement, the use of which has been superseded by them.

152. The quality of the *sand* used in making mortar is by no means unimportant. It should be clean and sharp; *i.e.* angular, and perfectly free from all impurities. The purer the lime the finer should be the quality of the sand, the pure limes requiring finer, and the cements a coarser sand than the hydraulic limes. From two to three parts of sand are mixed with Portland cement.

CONCRETE.

153. Rubble masonry, formed of small stones bedded in mortar, appears to have been commonly used in England from an early period; and similar work, cemented with hydraulic mortar, was constantly made use of by the Romans in their sea-works, of which many remains exist at the present day in a perfectly sound state.

154. This mode of forming foundations, in situations where solid masonry would be inapplicable, has been revived in modern times; in England under the name of concrete, and on the Continent under the name of *béton.*

155. Concrete is usually made with gravel or broken bricks, stones, or clinker, sand, lias lime, or Portland cement, mixed together with water in varying proportions to suit particular requirements.

Portland cement concrete with gravel finely broken (to pass an $1\frac{1}{2}$-inch ring), bricks, stones or clinker, and sand, in the proportion of about one part by measure of best Portland cement to four parts of broken aggregate and one

of sand is the mixture most generally used for upper floors or other similar work requiring tensile strength. For foundation work, the concrete need not be so strongly gauged, nor is it necessary to have so finely broken an aggregate, the most serviceable mixtures are in the proportion of one part by measure of cement to six of aggregate made up of large stuff to pass a $2\frac{1}{2}$-inch ring with sufficient sand, gravel, or other fine stuff to fill up all the interstices when mixed. It is important that the mixings should be thoroughly made—the fine stuff or matrix, *i.e.*, cement and sand, being turned over two or three times before the water is added, and then the matrix and aggregate should be turned over twice and thoroughly incorporated before being placed in position.

The Portland cement for concreting should be very finely ground, only leaving a residue of 5 per cent. when sifted through a sieve having 5,625 meshes per square inch, as the residue has no setting properties. It should weigh 112 lbs. per striked bushel; for heavy cements through slow setting have the greatest ultimate strength, and it should be capable of withstanding a tensile strength of 400 lbs. per square inch, after the briquette has been immersed in water seven days immediately following its mixing with water to form the briquette, and that strength should show no deterioration but increase gradually for 21 days more.

Lias lime is sometimes used for foundation concrete, the ground quality of course being employed, or the lump variety thoroughly slaked before being mixed with the sand.

156. Asphalte, so much in use at the present day for foot-pavements, terrace-roofs, &c., is made by melting the asphalte rock, which is a carbonate of lime intimately combined with bitumen, and adding to it a small portion of mineral tar, which forms a compact semi-elastic solid, ad-

mirably adapted for resisting the effects of frost, heat, and wet.

Many artificial asphaltes have been brought under public notice from time to time, but they are all inferior to the natural asphalte, in the intimate combination of the lime and bitumen, which it appears impossible to effect thoroughly by artificial means.

METALS.

157. The metals used as building materials are iron lead, copper, zinc, and tin.

158. *Iron.*—Iron is used by the builder in three different states, viz. cast iron, wrought iron, and steel, the differences between them depending on the proportion of carbon combined with the metal; cast iron containing the most, and wrought iron the least, and steel an intermediate quantity.

159. Previous to the middle of the last century, the smelting of iron was carried on with wood charcoal, and the ores used were chiefly from the secondary strata, although the clay ironstones of the coal measures were occasionally used.

The weald of Kent and Sussex* contained many iron works during the seventeenth century. That at Lamber hurst, near Tunbridge Wells in Sussex, is noted as having furnished the cast-iron railing round St. Paul's Cathedral. The tilt hammers used in forging bar iron were chiefly worked by water power. A large pool in Beeding Forest, near Horsham in Sussex, still retains the name of the Hammer Pond, and the former sites of many old forges in

* The clay ironstones of Sussex are very rich, and are still raised in considerable quantities, and shipped for Wales and Newcastle.

the wealden district may still be traced by the heaps of cinders which yet remain here and there, and by the local names to which the works gave rise.

160. The introduction of smelting with pitcoal coke during the last century caused a complete revolution in the iron trade. The ores now chiefly used are the clay ironstones of the coal measures, and the fuel, pitcoal or coke. Steam power is almost exclusively used for the production of the blast in the furnaces, and for working the forge hammers and rolling mills.

161. For the production of wrought iron in the ordinary manner, two distinct sets of processes are required. 1st. The extraction of the metal from the ore in the shape of cast iron. 2nd. The conversion of cast iron into malleable or bar-iron, by re-melting, puddling, and forging; the operations repeated three or four times, increasing the quality of the wrought iron as manipulation adds to its fibrous tenacity.

162. *Cast iron* is produced by smelting the previously calcined ore in a blast furnace, with a portion of limestone as a flux, and pitcoal or coke as fuel. The melted metal sinks to the bottom of the furnace by its greater specific gravity. The limestone and other impurities float on the top of the melted mass, and are allowed to run off, forming *slag* or *cinder*. The melted metal is run off from the bottom of the furnace into furrows made in a level bed of sand, producing foundry pig, which is used for remelting into finished castings suitable for the architect and engineer, and forge pig which is converted into steel and wrought iron.

163. In the year 1827, it was discovered that by the use of heated air for the blast, a great saving of fuel could be effected, as compared with the cold blast process.

The hot blast is now very extensively in use, and has the double advantage of requiring less fuel to bring down an equal quantity of metal, and of enabling the manufacturer to use raw pitcoal instead of coke, so that a saving is effected both in the quantity and cost of the fuel.

For a considerable time after its introduction it was held in great disrepute, which, however, may be chiefly attributed to the inferior quality of materials used, the power of the hot blast in reducing the most refractory ores offering a great temptation to obtain a much larger product from the furnace than was compatible with the good quality of the metal. The use of the hot blast by firms of acknowledged character has greatly tended to remove the prejudice against it; and in many iron works of high character, nothing but the hot blast with pitcoal is used in the smelting furnaces the use of coke being confined to the subsequent processes.

Perhaps it may be laid down as a general principle, that where the pig iron is re-melted with coke in the cupola furnace, for the purposes of the ironfounder, or refined with coke in the conversion of forge pig into bar iron, it is of little consequence whether the reduction of the ore has been effected with the hot or the cold blast; but where castings have to be run directly from the smelting furnace, the quality of the metal will, no doubt, suffer from the use of the former.

164. Cast iron is divided by ironfounders into three qualities. No. 1, or *black cast iron*, is coarse-grained, soft, and not very tenacious. When re-melted it passes into No. 2, or *grey cast iron*. This is the best quality for castings requiring strength: it is more finely grained than No. 1, and is harder and more tenacious. When repeatedly re-melted it becomes excessively hard and brittle, and passes into No. 3, or *white cast iron*, which is only used for the commonest

castings, as sash-weights, and similar articles. White cast iron, if produced direct from the ore, is an indication of derangement in the working of the furnace, and is unfit for the ordinary purposes of the founder, except to mix with other qualities.

165. Stancheons and similar solid articles are cast in sand moulds, enclosed in iron frames or *boxes*, each mould requiring an upper and lower box. A mould is formed by pressing sand firmly round a wooden *pattern*, which is afterwards removed, and the melted metal poured into the space thus left through apertures made for the purpose.

The moulds for ornamental work and for hollow castings are of a more complicated construction, which will be better understood from actual inspection at a foundry than from any written description.

Almost all irons are improved by admixture with others, and, therefore, where superior castings are required they should not be run direct from the smelting furnace, but the metal should be re-melted in a cupola furnace, which gives the opportunity of suiting the quality of the iron to its intended use. Thus, for delicate ornamental work, a soft and very fluid iron will be required, whilst, for girders and castings exposed to cross strain, the metal will require to be harder and more tenacious. For bed-plates and castings which have merely to sustain a compressing force, the chief point to be attended to is the hardness of the metal.

Castings should be allowed to remain in the sand until cool, as the quality of the metal is greatly injured by the rapid and irregular cooling which takes place from exposure to air if removed from the moulds in a red-hot state, which is sometimes done in small foundries to economise room.

Staffordshire, Shropshire, and Derbyshire afford the best irons for castings. The Scotch iron is much esteemed for hollow wares, and has a beautifully smooth surface, which may be noticed in the stoves and other articles cast by the Carron Company.

The Welsh iron is principally used for conversion into bar iron.

166. The conversion of forge pig into bar iron or steel is effected by a variety of processes, which have for their object the freeing the metal from the carbon and other impurities combined with it, so as to produce as nearly as possible the pure metal, or the inclusion of a defined quantity of carbon as in the case of steel.

The process for making wrought iron has been alluded to in paragraph 161.

Steel is made by several processes :—

1st. By adding carbon to wrought iron in the case of blister and spring steels.

2nd. By extracting the carbon from pig iron and adding the proper proportion in the form of spiegclieten. (Bessemer patent.)

3rd. By adding scrap iron to the heated pig, and then such proportion of carbon as is found necessary by analysis and examination. (Siemens-Martin process.)

167. *Lead.*—Lead is used by the mason for securing dowels, coating iron cramps, and similar purposes, *see* Section IV., Plumber.

Lead is also used by the smith in fixing iron railings, and other work where iron is let into stone; but the use of lead in contact with iron is always to be avoided, if possible, as it has an injurious effect upon the latter metal, the part in contact with the lead becoming gradually softened. Sulphur is best for the purpose.

The chief value of lead, however, to the builder, is as a covering for roofs, and for lining gutters, cisterns, &c., for which uses it is superior to any other metal. For these purposes the lead is cast into sheets, and then passed between rollers in a *flatting-mill*, until it has been reduced to the required thickness, when it becomes milled-lead.

Cast-lead is often made by plumbers themselves from old lead taken in exchange; but it is very inferior to the *milled lead* of the manufacturer, being not so compact, and often containing small air-holes, which render it unfit for any but inferior purposes.

168. *Copper.*—*See* Section IV., Coppersmith.

169. *Zinc.*—*See* Section IV., Zincworker.

170. *Brass* is an alloy of copper and zinc, the best proportions being nearly two parts of copper to one of zinc.

171. *Bronze* is a compound metal, composed of copper and tin, to which are sometimes added a little zinc and lead.

The best proportions for casting statues and bas-reliefs appear to be attained when the tin forms about ten per cent. of the alloy.

By alloying copper with tin, a more fusible metal is obtained, and the alloy is much harder than pure copper; but considerable management is required to prevent the copper from becoming refined in the process of melting, a result which has frequently happened to inexperienced founders.

172. *Bell-metal* is composed of copper and tin, in the proportion of 78 per cent. of the former to 22 per cent. of the latter.

SECTION III.

STRENGTH OF MATERIALS.

173. There are three principal actions to which the materials of a building are exposed—namely: *Compression*, as in the case of the stones in a wall; *Tension*, as in the case of a king-post or tie-beam; and *Cross-strain*, as in the case of a bressummer, floor-joists, &c. Only against cross-strain are precautions especially necessary, as in all ordinary cases the resistance of the materials used for building is far beyond any direct crushing or pulling force that is likely to be brought upon them.

174. *Resistance to Compression.*—The following table will give an approximate idea of the powers of several building materials to resist compression:

		Crushed at per foot superficial. Tons.
Good common bricks	average	223
Ditto, built in mortar	„	32
Ditto, in cement	„	61
Blue bricks	„	780
Ditto built in mortar	„	114
Ditto built in cement	„	135
Sandstones	from	350
Limestones	from	250
Granite	about	1100

The following are for per inch sectional area, but must be considered as to bending :—

	Tons.	cwts.
Oak		13
Cast Iron	40	
Fir		7
Wrought iron	20	
Steel	30	

Cast iron may be considered as practicably incompressible ; *wrought iron* may be flattened under great pressure, but cannot be crushed. *Timber* may be considered, for practical purposes, as nearly incompressible, when the weight is applied in the direction of the fibres, as in the case of a wooden story-post ; but the softer kinds, as fir, offer little resistance, when the weight is applied at right angles to the fibres, as in the case of the sill of a partition ; and, besides this, timber, however well-seasoned, will always shrink, more or less, in the direction of its thickness, so that no important bearings should be trusted to it.

175. *Resistance to Tension.*—The principal building materials that are required to resist direct tension are *timber* and *wrought iron.*

The following table shows the weight in tons required to tear asunder bars 1-inch square of the following materials :—

	Tons.
Oak	5
Fir	$1\frac{1}{2}$
Cast Iron	$7\frac{1}{2}$
Wrought Iron	25
Steel	32

Cast iron, however, although included in the above table,

is an unsuitable material for the purpose of resisting tension, being comparatively brittle. With regard to *timber*, it is practically impossible to tear asunder a piece of even moderate size, by force applied in the direction of the fibres, and therefore the dimensions of king-posts, tie-beams, and other timbers which have to resist a pulling force, are regulated by the necessity of forming proper joints and connections with the other part of the framing to which they belong, rather than by their cohesive strength. But it must be borne in mind, that although the strength of all kinds of timber is very great in the direction of the fibres, the lateral cohesion of the annual rings is in many kinds of wood very slight, and must be assisted by iron straps in all doubtful cases. The architects of the middle ages executed their magnificent wooden roofs without these aids, but they worked in oak, and not in soft fir, which would split and rend if treated in the same way.

Wrought iron is extensively used for bolts, straps, tie rods, and all purposes which require great strength, with small sectional area; one-fourth of the breaking weight is usually said to be the limit to which it should be strained; but, in all probability, this amount might be doubled without any injurious effects.

176. *Cross Strain.*—In calculating the strength of beams when exposed to cross or transverse strain, two principal considerations present themselves: (1) The mechanical effect which any given load will produce under varying conditions of support; and (2) The resistance of the beam, and the manner in which this is affected by the form of its section.

177. *Mechanical Effect of a given Load under varying Circumstances.*—If a rectangular beam be supported at each

end and loaded in the middle, the strength of the beam, its section remaining the same, will be inversely as the distance between the supports, the weight acting with a leverage which increases at this distance.* If a beam be fixed at one end and weighted at the other (Fig. 70), its

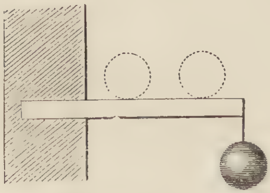


Fig. 70.

strength will be half that of a similar beam of double the length supported as first described (Fig. 71). A parallel case to this is that of a beam supported in the middle and

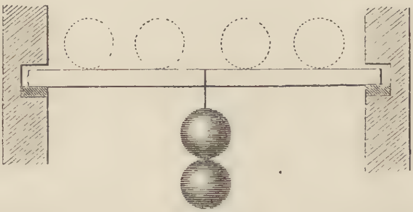


Fig. 71.

* It may be as well to observe that, although this is true as to the strength of beams under ordinary circumstances, it does not hold good when the loading is carried to the breaking point, the deflection of the beam causing an increase or diminution of the leverage according to the mode of support. The difference of strength arising from this cause is, however, too trifling to be taken into consideration, except in delicate experiments on the ultimate strength of beams.

loaded at the ends (Fig. 72). In each of the above cases the beam will bear double the load if it be equally distri-

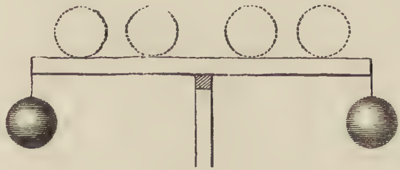


Fig. 72.

buted over its whole length, as shown by the dotted lines; and lastly, the strength of a beam firmly fixed at the ends is to its strength when loosely laid on supports as 3 to 2 (*see* Fig. 73).

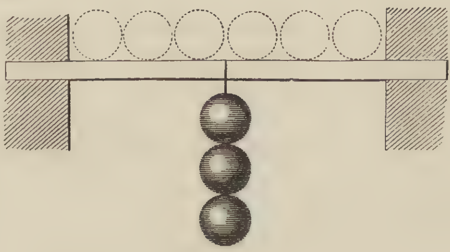


Fig. 73.

These results may be simply expressed thus :—

Let s be the weight which would break a beam of given length and scantling fixed at one end and loaded at the other;

then $2\ s$ would break the same beam fixed at one end and uniformly loaded;

$4\ s$ would break the same beam supported at each end and loaded in the middle;

6 s would break the same beam fixed at each end and loaded in the middle;

8 s would break the same beam supported at each end and uniformly loaded;

12 s would break the same beam fixed at each end and uniformly loaded.

178. 2nd. *Resistance of the Beam.*—If a beam be loaded so as to produce fracture, this will take place about a centre or neutral axis, below which the fibres will be *torn* asunder, and above which they will be crushed. This may be very clearly illustrated by drawing a number of parallel lines with a soft pencil on the edge of a piece of India rubber, and bending it round, when it will be seen that the lines are brought closer together on the concave, and stretched further asunder on the convex side, whilst, between the two edges, a neutral line may be traced, on which the divisions remain of the original size, which neutral line divides the fibres that are subjected to compression from those in a state of tension (*see* Fig. 74.)

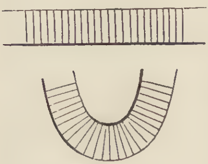


Fig. 74.

The resistance of a rectangular beam will, therefore, depend, 1st, on the number of fibres, which will be proportionate to its breadth and depth; 2nd, on the distance of those fibres from the neutral axis, and the consequent leverage with which they act, which will also be as the depth; and lastly, on the actual strength of the fibres, which will vary with different materials, and can only be determined approximately from actual experiments on rectangular beams of the same material as those whose strength is required to be estimated.

179. Cast iron beams or girders in which there must, on

account of the disparity in strength to resist tension and compression, be a great variation between the flanges, are now entirely superseded by steel joists which are also more reliable under sudden changes.

180. Steel joists are rolled to certain sizes according to the rolls the manufacturer has amongst his plant, and they are called stock sizes, and most makers have tables of the loads each of their girders will carry at various spans. It is easy for anyone to ascertain from their books what certain joists will carry, but it is to be noted that joists should seldom be more than twenty times their depth in length, and care should be taken as to the nature of the load, because a concentrated load causes double the strain of a uniform or distributed weight, which is the class of load on which the makers' calculations are based, and it is always advisable to take one-fourth of the breaking load as the safe load except in cases of bridges and the like, where one-fifth would be the more secure.

181. Steel joists are rolled up to a depth of 24 inches, but the depth allotted in a building seldom allows of such a joist being used.

It is advisable to select a joist in depth equal to one-twentieth the span, and if such joist cannot bear the weight it must be compounded by putting two or more together, and connecting them by one or more plates riveted on top and bottom.

182. The strength of any beam can be ascertained for a distributed load by the following method :—

$$\frac{8 \text{ times depth} \times \begin{matrix}\text{nett. sectional area}\\ \text{of one flange.}\end{matrix} \times \text{constant}}{\text{Span in inches.}}$$

The result will be the safe or breaking load according to the constant used.

The constant of safe loads may be :—

Wrought Iron	will resist	safely	4	tons	compression	per superficial	inch.
,,	,,	,,	5	,,	tension	,,	,,
Cast	,,	,,	$1\frac{1}{2}$	,,	,,	,,	,,
,,	,,	,,	8	,,	compression	,,	,,
Steel	,,	,,	6	,,	,,	,,	,,
,,	,,	,,	6	,,	tension	,,	,,
Oak	,,	,, about	16	cwt.	,,	,,	,,
,,	,,	,, ,,	13	,,	compression	,,	,,
Memel	,,	,, ,,	10	,,	,,	,,	,,
,,	,,	,, ,,	12	,,	tension	,,	,,
Fir	,,	,, ,,	10	,,	,,	,,	,,
,,	,,	,, ,,	7	,,	compression	,,	,,

and in working out rectangular beams it must not be forgotten that there must be an adequate portion above the

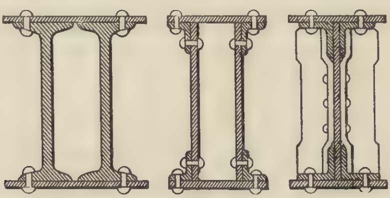


Fig. 75. Fig. 75A. Fig. 75B.

neutral axis to resist compression, and below a requisite area to resist tension.

Steel joists, plates, angles, channels, and tees are utilised to make compound girders as fig. 75, box girders as fig. 75A, and plate girders as fig. 75B.

183. *Trussed Timber Beams.*—Timbers exposed to severe strain require to be *trussed* with iron, and this may be done in two ways: 1st, by inserting cast-iron struts, as in fig. 76, thus placing the whole, or nearly the whole, of the woodwork in a state of tension; 2nd, by wrought-iron tension

rods, as in fig. 77, which take the whole of the tension, whilst the timber is thrown entirely into compression. The latter mode of trussing is now very extensively used in strengthening the carriages of travelling cranes and for similar purposes; and, by its use, a balk of timber which will barely support its own weight safely without assistance,

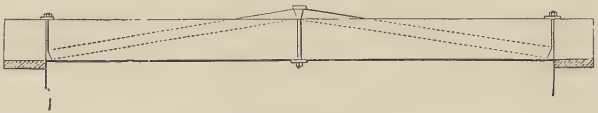


Fig. 76.

may be made to carry a load of many tons without sensible deflection.

184. When a piece of timber, whose length is not less than 8 or 10 times its diameter, is compressed in the direction of its length, as in the case of a wooden story-post supporting a bressummer, it will give way if loaded beyond a certain point, not by crushing, but by bending, and will ultimately be destroyed by the cross strain, just as a horizontal beam would be by vertical pressure applied at

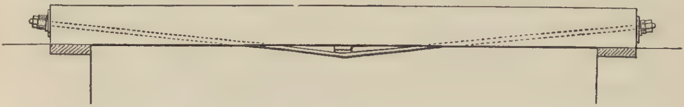


Fig. 77.

right angles to the fibres. The rules for determining the dimensions of a piece of timber to support a given weight without sensible flexure are very complicated, and are of little practical value, as they depend upon the condition that the pressure is exactly in the direction of the axis of the post—a condition rarely fulfilled in practice.

185. Wooden story-posts have been to a great extent superseded by the use of cast-iron pillars, which possess great strength with a small sectional area, and are on that account particularly well adapted to situations where it is of consequence to avoid obstructing light, as in shop-fronts.

In determining the design of a cast-iron pillar, whose length is 20 or 30 times its diameter, two points have to be considered: 1st, the liability to flexure; 2nd, the risk of the ends being crushed by the load not acting in the direction of the axis of the pillar.

The resistance to flexure is greatly increased by enlarging the bearing surface at the ends of the pillar, as in fig. 78, which, on the other hand, increases the liability of the ends to fracture, in the event of the load being thrown on the side instead of on the centre of the column, by any irregular settlement of the building. The judicious architect will, therefore, take a mean course, swelling out the capitals and bases of his cast-iron pillars enough to prevent their shafts from bending, but at the same time avoiding any thin flanges or projections, which might be liable to be broken. No theoretical rule for determining the proportions of a cast-iron pillar depending on the weight to be supported can be depended on in practice. The real measure of the strength of a cast-iron story-post must be the power of resisting any lateral force which may be brought against it; and as a slight blow will suffice to fracture a pillar which is capable of supporting a vertical pressure of very many tons, we have only to make sure of the lateral strength, and we are quite certain to be on the safe side as regards any vertical pressure which it may have to sustain.

Fig. 78.

186. Besides the above cases of transverse strain, there are others arising from irregular settlements, which are amongst the greatest difficulties with which the builder has to contend. Thus, to take a familiar instance, the window sills of a dwelling-house are often broken by the settlement of the brickwork being greater in the piers than under the sills, from the greater pressure on the mortar joints; and this will take place with a difference of settlement which can scarcely be detected, even by careful measurement. We need not here enlarge on this subject, as we have several times in the preceding pages had occasion to notice both the causes of irregular settlement, and the precautions to be taken for its prevention.

Steel stancheons of H. section or of channels, angles, tees, II's and plates compounded together are becoming more used than cast iron. The caps and bases must be made of plates, angles, and gussets riveted together, of such a character that the weight may be equally distributed over the padstones or other bearing surfaces on which they are to be erected.

SECTION IV.

USE OF MATERIALS.

EXCAVATOR.

187. The digging required for the foundations of common buildings usually forms part of the business of the bricklayer, and is paid for at per cubic yard, according to the depth of the excavation, and the distance to which the earth has to be wheeled; this being estimated by the *run* of 20 yards.

In large works, which require coffer-dams and pumping apparatus to be put down before the ground can be got out for the foundations, the work assumes a different character, and is paid for accordingly; the actual excavation being only a small item of the total cost compared with those of dredging, piling, puddling, shoring, pumping, &c.

The methods in use of constructing coffer-dams, driving piles, and executing other work connected with foundations, will be found described in the volume of this series on "Foundations and Concrete Works."

BRICKLAYER.

188. The business of a bricklayer consists in the execution of all kinds of work in which brick is the principal material; and in London it always includes tiling and

paving with bricks or tiles. Where undressed stone is much used as a building material, the bricklayer executes this kind of work also, and in the country, the business of the plasterer is often united with these branches.

189. The tools of the bricklayer are the *trowel*, to take up and spread the mortar, and to cut bricks to the requisite length: the *brick axe*, for shaping bricks to any required bevel; the *tin saw*, for making incisions in bricks to be cut with the axe, and a *rubbing stone*, on which to rub the bricks smooth after being roughly axed into shape. The *jointer* and the *jointing-rule* are used for *running* the centres of the mortar-joints. The *raker*, for raking out the mortar from the joints of old brickwork previous to re-pointing. The *hammer*, for cutting chases and splays. The *banker* is a piece of timber about 6 feet long, raised on supports to a convenient height to form a table on which to cut the bricks to any required gauge, for which *moulds* and *bevels* are required. The *crowbar*, *pick-axe*, and *shovel* are used in digging out the foundations, and the *rammer* in punning the ground round the footings, and in rendering the foundation firm where it is soft by beating or ramming.

To set out the work and to keep it true, the bricklayer uses the *square*, the *level*, and the *plumb-rule;* for circular or battering work he uses *templets* and *battering-rules; lines* and *pins* are used to lay the courses by; and *measuring-rods* to take dimensions. When brickwork has to be carried up in conjunction with stonework, the height of each course must be marked on a *gauge-rod*, that the joints of each may coincide.

190. The bricklayer is supplied with bricks and mortar by a labourer, who carries them in a *hod*. The labourer also makes the mortar, and builds and strikes the scaffolding.

191. The bricklayers' scaffold is constructed with *stan-*

dards, *ledgers*, and *putlogs*. The standards are fir poles, from 40 to 50 ft. long, and 6 or 7 in. diameter at the butt ends, which are firmly bedded in the ground. When one pole is not sufficiently long, two are lashed together, top and butt, the lashings being tightened with wedges. The ledgers are horizontal poles placed parallel to the walls, and lashed to the standards for the support of the putlogs. The putlogs are cross pieces usually made of birch, and about 6 ft. long, one end resting in the wall, the other on a ledger. On the putlogs are placed the scaffold boards, which are stout boards hooped at the ends to prevent them from splitting.

192. A bricklayer and his labourer can lay in a single day of 9 hours about 1,000 bricks, or about two cubic yards, but generally his day's work amounts to about 400 bricks.

193. The tools required for tiling are—the *lathing-hammer*, with two gauge marks on it, one at 7, and the other at $7\frac{1}{2}$ inches; the *iron lathing staff*, to clinch the nails; the *trowel*, which is longer and narrower than that used for brickwork; the *bosse*, for holding mortar and tiles, with an iron hook to hang it to the laths or to a ladder; and the *striker*, a piece of lath about 10 in. long, for clearing off the superfluous mortar at the feet of the tiles.

194. Brickwork is measured and valued by the rod, or by the cubic yard, the price including the erection and use of scaffolding, but *not* centering to arches. Bricknogging, pavings, and facings, by the superficial yard. Digging and steining of wells and cesspools by the foot in depth, according to size, the price increasing with the depth. Plain tiling and pantiling are valued per square of 100 feet or per yard superficial.

A journeyman bricklayer receives from 6*s.* to 7*s.* 6*d.*, and a labourer from 3*s.* 9*d.* to 5*s.* 3*d.* a day.

The following memoranda may be useful :—

Weight of different kinds of Earth.

13 cubic feet of		chalk weigh one ton.	
17	,,	clay	,,
18	,,	nightsoil	,,
$21\frac{3}{4}$	,,	gravel	,,
$23\frac{1}{2}$	,,	sand	,,

Nightsoil is removed in carts containing 45 cubic feet, or $2\frac{1}{2}$ tons.

Twenty-seven cubic feet or 1 cubic yard is called a single load, and 2 cubic yards a double load.

A measure of lime is 27 cubic feet and contains 21 striked bushels.

A bricklayer's hod measures 1 ft. 4 in. × 9 in. × 9 in., and contains 10 bricks.

A rod of brickwork measures $16\frac{1}{2}$ ft. square, $1\frac{1}{2}$ brick thick (known as reduced or standard thickness), or 272 ft. 3 in. superficial, or 306 cubic feet, or $11\frac{1}{3}$ cubic yards.

Table of the Sizes and Weights of various Articles.

Description.	Length.		Breadth.		Thickness.		Weight.	
	ft.	in.	ft.	in	ft.	in.	lbs.	oz.
Stock bricks . . each	0	$8\frac{3}{4}$	0	$4\frac{1}{4}$	0	$2\frac{1}{2}$	5	0
Paving do. . . ,,	0	9	0	$4\frac{1}{2}$	0	$1\frac{3}{4}$	4	0
Dutch clinkers . . ,,	0	$6\frac{1}{4}$	0	3	0	$1\frac{1}{2}$	1	8
12-in. paving tiles . ,,	0	$11\frac{3}{4}$	0	$11\frac{3}{4}$	0	$1\frac{1}{2}$	13	0
10-in. do. . ,,	0	$9\frac{3}{4}$	0	$9\frac{3}{4}$	0	1	8	9
Pantiles . . . ,,	1	$1\frac{1}{2}$	0	$9\frac{1}{2}$	0	$0\frac{1}{2}$	5	4
Plain tiles . . . ,,	0	$10\frac{1}{2}$	0	$6\frac{1}{2}$	0	$0\frac{5}{8}$	2	5
Pantile laths per 10 ft. bundle	120	0	0	$1\frac{1}{2}$	0	1	4	6
Do. ,, 12 ft. do.	144	0	0	$1\frac{1}{2}$	0	1	5	0
N.B.—A bundle contains twelve laths.								
Plain tile laths per bundle .	500	0	0	1	0	$0\frac{3}{4}$	3	0
N.B.—Thirty bundles of laths make a load.								

A rod of brickwork, laid four courses to a foot in height, requires 4353 stock bricks.

Ditto, 11½ in. to 4 courses, 4533 stock bricks.

Ditto, 13¼ in to 4 courses, 4000 3 in. bricks.

These calculations are made without allowing for waste, which is unnecessary, because the space occupied by flues, bond timber, &c., and for which no deduction is made, more than compensates for any waste; and in building dwelling-houses, 4300 stocks to a rod is sufficient.

If laid dry, 5370 stocks to the rod.

4900 ditto, in wells and circular cesspools.

A rod of brickwork, laid 4 courses to gauge 12 in., contains 235 cubic feet of bricks and 71 cubic feet of mortar, and weighs about 15 tons.

A rod of brickwork requires 1½ cubic yard of chalk lime and 3 single loads of sand, or 1 cubic yard of stone lime and 3½ loads of sand, or 17 bushels of cement and 51 bushels of sharp sand, mixed 1 to 3.

A cubic yard of mortar requires 9 bushels of lime and 1 load of sand.

Lime and sand, and likewise cement and sand, lose ⅓rd of their bulk when made into mortar.

The proportion of mortar or cement, when made up, to the lime or cement and sand before made up, is as 2 to 3.

Lime or cement and sand to make mortar require as much water as is equal to ⅓rd of their bulk.

A cubic yard of concrete requires 34 cubic feet of material; or, if the gravel is to the lime as 6 to 1, a cubic yard of concrete will require 1·1 cubic yard of gravel and sand and 3 bushels of cement.

Facing requires 7 bricks per foot superficial.

Gauged arches, 10 ditto ditto.

Bricknogging per yard superficial requires 30 bricks on edge, or 45 laid flat.

195. *Paving.*

Stock bricks laid flat require		36	per yard superficial.
Ditto on edge	"	52	"
Paving bricks laid flat	"	36	"
Ditto on edge	"	82	"
Dutch clinkers ditto	"	140	"
12-inch paving tiles	"	9	"
10-inch ditto	"	13	"

196. *Tiling.*—

Description.	Gauge in Inches.	No. required per Square.
With pantiles	12	150
Ditto	11	164
Ditto	10	180

N.B.—A square of pantiling requires 1 bundle of laths and $1\frac{1}{4}$ hundred of sixpenny nails.

Description.	Gauge in Inches.	Lap in Inches.	No. required per Square.
With plain tiles	4	$2\frac{1}{2}$	600
Ditto	$3\frac{3}{4}$	3	650
Ditto	$3\frac{1}{2}$	$3\frac{1}{2}$	700

N.B. A square of plain tiling requires from 300 to 350 ft. of laths, 1 peck of tile pins, and 3 hods of mortar.

Plain tiles laid flat . . .			210

MASON.

197. The business of the mason consists in *working* the stones to be used in a building to their required shape, and in *setting* them in their places in the work. Connected

with the trade of the mason are those of the *Stonecutter*, who *hews* and cuts large stones roughly into shape preparatory to their being *worked* by the mason, and of the *Carver*, who executes the ornamental portions of the stone-work of a building, as enriched cornices, capitals, &c.

198. Where the value of stone is considerable, it is sent from the quarry to the building in large blocks, and cut into slabs and scantlings of the required size with a stone-mason's saw, which differs from that used in any other trade in having no teeth. It is a long thin plate of steel, slightly jagged on the bottom edge, and fixed in a frame; and, being drawn backwards and forwards in a horizontal position, cuts the stone by its own weight. To facilitate the operation, a heap of sharp sand is placed on an inclined plane over the stone, and water allowed to trickle through it, so as to wash the sand into the saw-cut. Of late years machinery worked by steam-power has been used for sawing marble into slabs to a very great extent, and has almost entirely superseded manual labour in this part of the manufacture of chimney pieces.

Some freestones, as Bath-stone, are so soft as to be easily cut with a toothed saw worked backwards and forwards by two persons.

The harder kinds of stones, as granites and gritstones, are brought roughly into shape at the quarry, with an axe or a scappling hammer, and are then said to be *scappled*.

199. The tools used by the mason for cutting stone consists of the *mallet* and *chisels* of various sizes. The mason's mallet differs from that used by any other artisan, being similar to a dome in contour, excepting a portion of the broadest part, which is rather cylindrical; the handle is short, being only sufficiently long to enable it to be firmly grasped.

In London the tools used to work the faces of stone are the *point*, which is the smallest description of chisel, being never more than a quarter of an inch broad on the cutting edge; the *inch tool;* the *boaster*, which is 2 inches wide; and the *broad tool*, of which the cutting edge is 3½ inches wide. The tools used in working mouldings and in carving are of various sizes, according to the nature of the work.

Besides the above cutting tools the mason uses the *banker* or bench, on which he places his stones for convenience of working, and *straight edges*, *squares*, *bevels*, and *templets* for marking the shapes of the blocks, and for trying the surfaces as the work proceeds. Any angle greater or less than a right angle is called a bevel angle, and a *bevel* is formed by nailing two straight edges together at the required angle; a *bevel square* is a square with a shifting stock which can be set to any required bevel. A templet is a pattern for cutting a block to any particular shape; when the work is moulded the templet is called a *mould.* Moulds are commonly made of sheet zinc, carefully cut to the profile of the mouldings with shears and files.

For setting his work in place the mason uses the *trowel*, *lines*, and *pins*, the *square* and *level*, the *plumb* and *battering rules*, for adjusting the faces of upright and battering walls.

200. The mason's scaffold is double, that is, formed with two rows of standards, so as to be totally independent of the walls for support, as putlog holes are inadmissible in masonry.

During the last ten years the construction of scaffolds with round poles lashed with cords has been entirely superseded in large works built of stone by a system of scaffolding of square timbers connected by bolts and dog irons.

The hoisting of the materials is performed from these scaffolds by means of a travelling crane, which consists of a double travelling carriage running on a tramway formed on stout sills laid on the top of two parallel rows of standards. The crab-winch is placed on the upper carriage, and, by means of the double motion of the two carriages, can be brought with great ease and precision over any part of the work lying between the two rows of standards.

The facilities which are afforded by these scaffolds and travelling cranes for moving heavy weights over large areas, have led to their extensive adoption, not only in the erection of buildings, but on landing wharfs, masons and iron-founders' yards, and similar situations, where a great saving of time and labour is effected by their use.

Scaffolding of square timbers appears to have been little used in England before A.D. 1837, when Messrs. Cubitt, of Gray's Inn Road, applied it to the erection of the entrance gateway of the Euston station of the North-Western Railway. Since then it has been very generally used in large works, amongst which may be mentioned the Reform Club House, in A.D. 1838, and the Nelson Column, commenced A.D. 1840, where it was carried up in perfect safety to the height of 180 feet: and it has been used on a very large scale at the New Houses of Parliament.

Although used in Scotland more than in England this kind of scaffolding is not a new invention. It appears to have been used at Cologne Cathedral from the first commencement of that building in A.D. 1248. It was also used by Domenic Fontana in A.D. 1586, for erecting the Egyptian Obelisk in front of St. Peter's at Rome; and similar scaffolding was used in Paris in our own times, in erecting the Arc de l'Etoile and the Eglise de la Madeleine.

201. The moveable derrick crane is also much used in setting mason's work. It consists of a vertical post, supported by two timber backstays and a long moveable jib or derrick hinged against the post below the gearing.

By means of a chain passing from a barrel over a pulley at the top of the post, the derrick can be raised to an almost vertical, or lowered to an almost horizontal position, thus enabling it to command every part of the area of a circle of a radius nearly equal to the length of the derrick. This gives it a great advantage over the old gibbet crane, which only commands a circle of a fixed radius, and the use of which entails great loss of time from its constantly requiring to be shifted as the work proceeds.

Derrick cranes appear to have been first introduced at Glasgow, A.D. 1833, by Mr. York, since which their original construction has been very greatly improved upon, and they are now very extensively used and worked by steam.

202. In hoisting blocks of stone they are attached to the tackle by means of a simple contrivance called a *lewis*, which is shown in Fig. 79.

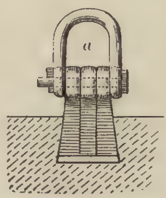


Fig. 79.

A tapering hole having been cut in the upper surface of the stone to be raised, the two side pieces of the lewis are inserted and placed against the sides of the hole; the centre parallel piece a is then inserted and secured in its place by a pin passing through all three pieces, and the stone may then be safely hoisted, as it is impossible for the lewis to draw out of the hole. By means of the lewis, in a slightly altered form from that here shown, stones can be lowered and set under water without difficulty, the lewis

being disengaged by means of a line attached to the parallel piece, the removal of which allows the others to be drawn out of the mortice.

203. In stone-cutting, the workman forms as many plane faces as may be necessary for bringing the stone into the required shape, with the least waste of material and labour, and on the plane surfaces so formed applies the moulds to which the stone is to be worked.

To form a plane surface, the mason first knocks off the superfluous stone along one edge of the block, as a, b (Fig. 80) until it coincides with a straight edge throughout its whole length; this is called a *chisel draught*. Another chisel

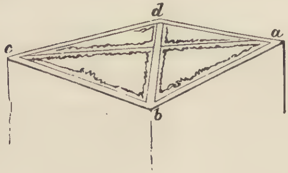


Fig. 80.

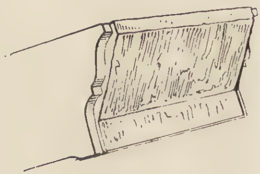


Fig. 81.

draught is then made along one of the adjacent edges, as b, c, and the ends of the two are connected by another draught, as a c; a fourth draught is then sunk across the last, as b, d, which gives another angle point d, in the same plane with a, b, and c, by which the draughts d a and a c can be formed; and the stone is then knocked off between the outside draughts until a straight edge coincides with its surface in every part.

To form cylindrical or moulded surfaces curved in one direction only, the workman sinks two parallel draughts at the opposite end of the stone to be worked, until they coincide with a mould cut to the required shape, and after-

wards works off the stone between these draughts, by a straight edge applied at right angles to them (Fig. 81).

The formation of conical or spherical surfaces is much less simple, and requires a knowledge of the scientific operations of stone-cutting, a description of which would be unsuited to the elementary character of these pages. The reader who wishes to pursue the subject is therefore referred to the volume of this series on "Masonry and Stone-cutting," where he will find the required information.

204. The finely-grained stones are usually brought to a smooth face, and rubbed with sand to produce a perfectly even surface.

In working soft stones, the surface is brought to a smooth face with the *drag*, which is a plate of steel, indented on the edge like the teeth of a saw, to take off the marks of the tools employed in shaping it.

The harder and more coarsely-grained stones are generally *tooled*, that is, the marks of the chisel are left on their face. If the furrows left by the chisel are disposed in regular order, the work is said to be *fair-tooled*, but if otherwise, it may be *random-tooled*, or *chiselled*, or *boasted*, or *pointed*. If the stones project beyond the joints, the work is said to be *rusticated*.

Granite and gritstone are chiefly worked with the scappling hammer. In massive erections, where the stones are large, and a bold effect is required, the fronts of the blocks are left quite rough, as they come out of the quarry, and the work is then said to be *quarry pitched*.

Many technical terms are used by quarrymen and others engaged in working stone; but they need not be inserted here, as they are mostly confined to particular localities beyond which they are little known, or perhaps bear a different signification.

205. When the mason requires to give to the joints of his work greater security than is afforded by the weight of the stone and the adhesion of the mortar, he makes use of *joggles*, *dowels*, and *cramps*.

Stones are said to be joggled together when a projection is worked out on one stone to fit into a corresponding hole or groove in the other (*see* Fig. 82). But this occasions great labour and waste of stone, and *dowel-joggels* are chiefly made use of, which are hard pieces of stone, cut to the required size, and let into corresponding mortices in the two stones to be joined together.

Fig. 82.

Dowels are pins of stone or metal used to secure the joints of stone-work in exposed situations, as copings, pinnacles, &c. The best material is copper, but the expense of this metal is against its use. If iron be made use of, it should be galvanized to prevent oxidation, or it will sooner or later, burst and split the work it is intended to protect. Dowels of slate are the cheapest and best.

Dowels are often secured in their places with lead poured in from above, through a small channel cut in the side of the joint for that purpose; but a good workman will eschew lead, which too often finds its way into bad work, and will prefer trusting to very close and workmanlike joints, carefully fitted dowels, and fine mortar; dowels should be made tapering at one end, which ensures a better fit, and renders the setting of the stone more easy for the workman.

Cramps are used as fastenings on the tops of copings and in similar situations; they should be made of copper—as iron in such exposed positions soon corrodes and does more harm than good. If copper cannot be afforded, slate dowels should be substituted or lead dovetails.

206. In measuring mason's work, the cubic content of

the stone is taken as it comes to the *banker*, without deduction for subsequent waste.

If the scantlings are large, an extra price is allowed for hoisting.

The labour in working the stone is charged by the superficial foot, according to the kind of work, as plain work, sunk work, moulded work, &c.

Pavings, landings, &c., and all stone less than 3 in. thick, are charged by the superficial foot.

Copings, curbs, window sills, &c., are charged per lineal foot.

Cramps, dowels, mortice holes, &c., are always charged separately.

A journeyman mason will receive from 6*s.* to 7*s.* 6*d.* per day, and the labourer from 3*s.* 9*d.* to 5*s.* 3*d.* per day ; but masons working at piece-work, or at any work requiring particular skill, will often earn much more.

The remuneration of a stone carver is dependent on his talent, and the kind of work he is engaged upon.

The following table of the weights of different kinds of stone will convey an idea of their relative hardness, and of the labour required to work them.

Table of the Weight of different kinds of Stone.

13	cubic feet of	marble	weigh one ton
$13\frac{1}{2}$	,,	granite	,,
14	,,	Purbeck stone	,,
$14\frac{1}{2}$	,,	Yorkshire stone	,,
16	,,	Derbyshire grit	,,
17	,,	Portland stone	,,
18	,,	Bath stone	,,

58 ft. superficial of 3-in. York paving weigh one ton ; and 70 ft. superficial of $2\frac{1}{2}$-in. York paving weigh one ton.

CARPENTER.

207. The business of the carpenter consists in framing timbers together, for the construction of roofs, partitions, floors, &c.

208. The carpenter's principal tools are the axe, the adze, the saw, and the chisel, to which may be added the chalk-line, plumb-rule, level, and square.

The work of the carpenter (it should be remarked) does not require the use of the plane, which is one of

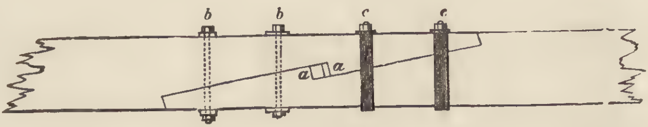


Fig. 83.

the principal tools of the joiner, and this forms the principal distinction between the two trades, the carpenter being engaged in the rough framework, and the joiner on the finishings and decorations, of buildings.

209. The principles of framing have been already fully described in the First Section of this work, and we shall therefore confine our remarks on the operations of the carpenter to a description of the principal joints made use of in framing.

Timbers that have to be joined in the direction of their length are *scarfed*, as shown in Fig. 83; the double wedges, *a a*, serve to bring the timbers *home*, when they are secured, either by bolts, as shown at *b b*, or by straps, as at *c c*, the latter being the most perfect and the most expensive fastening.

Fig. 84 shows the manner of connecting the foot of a principal rafter with a tie-beam. The bolt here shewn keeps the rafter in its place, and prevents it from slipping

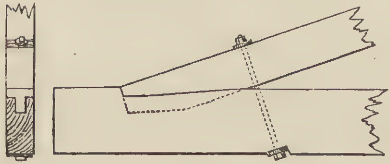


Fig. 84.

away from the abutment cut for it, which, by throwing the thrust on the tenon, would probably split it. The end of the rafter should be cut with a square butt, so that the shrinkage of the timber will not lead to any settlement.

The connection of the foot of a king-post with the tie-beam to be suspended from it is shown in Fig. 85.

The king-post should be cut somewhat short, to give the power of screwing up the framing after the timber has become fully seasoned. The tie-beam may be suspended from the king-post, either by a bolt, as shown, or by a strap passed round the tie-beam and secured by iron wedges or cotters, passing through a hole in the king-post; this last is the more perfect, but at the same time the more expensive of the two methods.

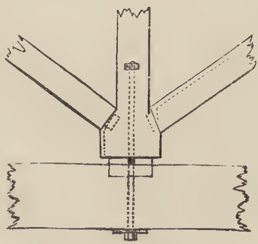


Fig. 85.

Fig. 85 also shows the manner in which the feet of the struts butt upon the king-post. They are slightly tenoned to keep them in their places.

The ends of a strut should be cut off as nearly square as possible, otherwise, when the timber shrinks, which it will always do, more or less, the thrust is thrown upon the edge only, which splits or crushes under the pressure, and causes settlement.

This is shown out by the dotted lines on the right-hand side of the cut. The dotted lines on the opposite side of the figure show a similar effect, produced by the shrinking of the king-post, for which there is no preventative but making it of oak, or some other hard wood. The same

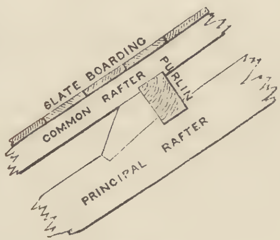


Fig. 86.

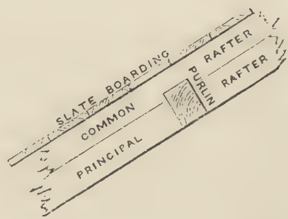


Fig 87.

observations apply to the connections of the principal rafters with the top of the king-post, which are managed in a precisely similar manner.

In Figures 86, 87, and 88, are shown different methods of fixing purlins, which are sufficiently explained by the figures to need no further description.

In Figures 41, 42, 43, and 44, are shown the modes of framing the ends of binding joists into girders, and of connecting the ceiling joists with the binders; and as these have been already described under the head of "Floors," it is unnecessary here to say anything further on the subject.

As a general rule, all timbers should be notched down to those on which they rest, so as to prevent their being moved either lengthways or sideways. Where an upright post has to be fixed between two horizontal sills, as in the case of the uprights of a common framed partition, it is simply tenoned into them, and the tenons secured with oak pins driven through the cheeks of the mortise.

210. The carpenter requires considerable bodily strength

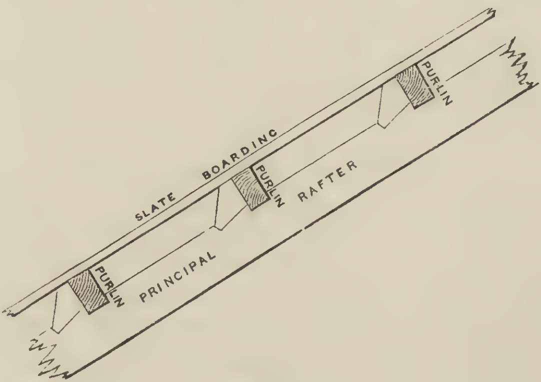


Fig. 88.

for the handling of the timbers on which he has to work; he should have a knowledge of mechanics, that he may understand the nature of the strains and thrusts to which his work is exposed, and the best method of preventing or resisting them; and he should have such a knowledge of working drawings as will enable him, from the sketches of the architect, to set out the *lines* for every description of centering and framing that may be entrusted to him for execution.

211. In measuring carpenters' work the tenons are in-

cluded in the length of the timber; this is not the case in joiners' work, in which they are allowed for in the price.

The labour in framing, roofs, partitions, floors, &c., is either valued at per square of 100 superficial feet, and the timber charged for separately, or the timber is charged as "fixed in place," the price varying according to the labour on it, as "cube fir in bond," "cube fir framed," "cube fir wrought and framed," &c. For shoring $\frac{1}{3}$rd of the value of the timber is allowed for use and waste.

The wages of a journeyman carpenter are from 6*s.* to 7*s.* 6*d.* per day.

JOINER.

212. The work of the joiner consists in framing and *joining* together the wooden finishings and decorations of buildings, both internal and external, such as floors, staircases, framed-partitions, skirtings, solid door and window frames, hollow or *cased* window frames, sashes and shutters, doors, columns and entablatures, chimney-pieces, &c., &c.

The joiner's work requires much greater accuracy and finish than that of the carpenter, and differs materially from it in being brought to a smooth surface with the plane wherever exposed to view, whilst in carpenters' work the timber is left rough as it comes from the saw.

213. The joiner uses a great variety of tools; the principal *cutting* tools are *saws*, *planes*, and *chisels.*

Of saws there are many varieties, distinguished from each other by their shape and by the size of the teeth.

The *ripper* has 8 teeth in 3 inches; the *half-ripper* 3 teeth to the inch; the *hand saw* 15 teeth in 4 inches; the *panel saw* 6 teeth to the inch.

The *tenon saw*, used for cutting tenons, has about 8 teeth

to the inch, and is strengthened at the back by a thick piece of iron, to keep the blade from buckling. The *sash saw* is similar to the tenon saw, but is backed with brass instead of iron, and has 13 teeth to the inch. The *dovetail saw* is still smaller, and has 15 teeth to the inch.

Besides the above, other saws are used for particular purposes, as the *compass saw*, for cutting circular work, and the *key-hole saw*, for cutting out small holes. The *carcase saw* is a large kind of dovetail saw, having about 11 teeth to an inch.

214. Planes are also of many kinds; those called *bench planes*—as the *jack plane*, the *trying plane*, the *long plane*, the *jointer*, and the *smoothing plane*, are used for bringing the stuff to a plane surface. The jack plane is about 18 in. long, and is used for the roughest work. The trying plane is about 22 in. long, and used after the jack plane for *trying up*, that is, taking off shavings the whole length of the stuff; whilst in using the jack plane the workman stops at every arm's length. The *long plane* is 2 ft. 3 in. long, and is used when a piece of stuff is to be tried up very straight. The *jointer* is 2 ft. 6 in. long, and is used for trying up or *shooting* the *joints*, in the same way as the trying plane is used for trying up the *face* of the stuff. The *smoothing plane* is small, being only 7½ in. long, and is used on almost all occasions for cleaning off finished work.

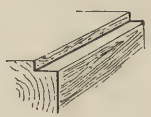


Fig. 89.

Rebate planes are used for sinking *rebates* (*see* Fig. 89), and vary in their size and shape according to their respective uses. Rebate planes differ from bench planes in having no handle rising out of the stock, and in discharging their shavings at the side. Amongst the rebate planes may be mentioned the *moving fillister* and the *sash fillister*, the

uses of which will be better understood by inspection than from any description.

Moulding planes are used for *sticking* mouldings, as the operation of forming mouldings with the plane is called. When mouldings are worked out with chisels instead of with planes, they are said to be worked *by hand*. Of the class of moulding planes, although kept separate in the tool chest, are *hollows* and *rounds* of various sizes.

There are other kinds of planes besides the above; as the *plough*, for sinking a groove to receive a projecting tongue; the *bead plane*, for sticking beads; the *snipe bill* for forming quirks; the *compass plane* and the *forkstaff plane* for forming concave and convex cylindrical surfaces. The shape and use of these and many other tools used by the joiner will be better understood by a visit to the joiner's shop than by any verbal description.

215. Chisels are also varied in their form and use. Some are used merely with the pressure of the hand, as the *paring chisel;* others, by the aid of the mallet, as the *socket chisel*,* for cutting away superfluous stuff; and the *mortise chisel*, for cutting mortises. The *gouge* is a curved chisel.

216. The joiner uses a great variety of boring tools, as the *brad-awl*, *gimlet*, and *stock and bit*. The last form but one tool, the *stock* being the handle, to the bottom of which may be fitted a variety of steel bits of different bores and shapes, for boring and widening out holes in wood and metal, as *countersinks*, *rimers*, and *taper shell bits*.

217. The *screw-driver*, *pincers*, *hammer*, *mallet*, *hatchet*, and *adze*, are too well known to need description.

The *gauge* is used for drawing lines on a piece of stuff parallel to one of its edges.

* Named from the iron forming a socket to receive a wooden handle.

The *bench* is one of the most important of the joiner's implements. It is furnished with a vertical *sideboard*, perforated with diagonal ranges of holes, which receive the *bench pin* on which to rest the lower end of a piece of stuff to be planed, whilst the upper end is firmly clamped by the *bench screw*.

The *mitre box* is used for cutting a piece of stuff to a *mitre* or angle of 45 degrees with one of its sides.

The joiner uses for setting out and fixing his work—the straight edge, the square, the bevel or square with a shifting blade, the mitre square, the level, and the plumb rule.

In addition to the tools and implements above enumerated, the execution of particular kinds of work requires other articles, as cylinders, templets, cramps, &c., the description of which would unnecessarily extend the limits of this volume.

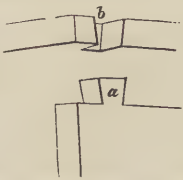


Fig. 90.

218. All the aforegoing tools would be required by a joiner if machines were not to be procured, but nowadays machines do all the planing, thicknessing, tenoning, mortising, scrolling, scribing and dovetailing—the joiner has only to set out the work, put it together, and fix it.

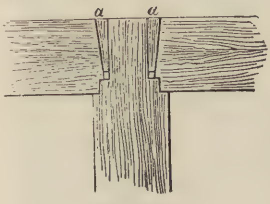


Fig. 91.

The manner of forming a *dovetail* is shown in Fig. 90. The projecting part, *a*, is called the *pin*, and the hole to receive it is called the *socket*.

Mortising is shown in Fig. 91; the projecting piece is called the *tenon*, and the hole formed to receive it the *mortise*. The

tenon is sometimes *pinned* in its place with oak pins driven through the cheeks of the mortise, but in forming doors, shutters, &c., the tenon is secured with tapering wedges driven into the mortise, which is cut slightly wider at the top than at the bottom, the adhesion of the glue with which the wedges are first rubbed over, making it impossible for the tenon afterwards to draw out of its place.

219. Joints in the length of the stuff may be either square, as at *a*, Fig. 92, or rebated, as at *b*, or grooved and

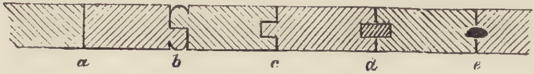


Fig. 92.

tongued, as at *c*, or grooved on each edge and a tongue let in, as at *d*, or dowelled with hardwood pins as *e*.

220. *Scribing* is the drawing on a piece of stuff the exact profile of some irregular surface to which it is to be made to fit: this is done with a pair of compasses, one leg of which is made to traverse the irregular surface, the other to *describe* a line parallel thereto along the edge of the stuff to be cut.

221. In the execution of circular, or, as it is termed, *sweep work*, there are two different methods by which the stuff can be brought to the required curve :—

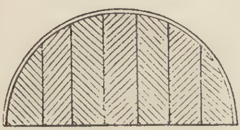


Fig. 93.

1st. It may be steamed and bent into shape.

2nd. It may be glued up in thicknesses, as shown in Fig. 93, which must, when thoroughly dry, be planed true, and, if not to be painted, covered with a thin veneer bent round it.

222. When a number of boards are secured together by cross-pieces or *ledges* nailed or screwed at the back, the work is said to be *ledged* (*see* Fig. 94). Ledged work is used for common purposes, as cellar doors, outside shutters, &c., and the door is prevented from sagging by the insertion of braces rising from the hanging side as Fig. 95, whch is called a *ledged and braced door*, or a further improvement may be made by framing together the styles, rails and braces, and

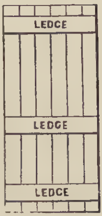


Fig. 94.

Fig. 95.

Fig. 96.

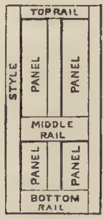


Fig. 97.

nailing thereon the boarding or cleading, the middle rail and braces being of less thickness than the styles, to allow of the boarding on them coming flush with the styles. *See* Fig. 96.

Panelled work (Fig. 97) consists of *styles* and *rails* mortised and tenoned together, and filled in with panels, the edges of which fit in grooves cut for that purpose in the styles and rails. Work is said to be *clamped* when it is prevented from warping or splitting by a rail at each end, as in Fig. 98; if the ends of the rails are cut off, as shown at *a*, it is said to be mitre clamped.

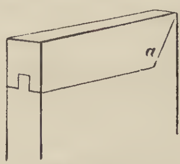


Fig. 98.

223. There are two ways of laying floors practised by joiners. In laying what is called a *straight joint* floor, from the joints between the boards running in an unbroken line

from wall to wall, each board is laid down and nailed in succession, being first forced firmly against the one last laid with a flooring cramp.

Folding floors are laid by nailing down first every fifth board rather closer together than the united widths of four boards, and forcing the intermediate ones into the space left for them by jumping upon them ; this method of laying floors is resorted to when the stuff is imperfectly seasoned and is expected to shrink, but it should never be allowed in good work.

The narrower the stuff with which a floor is laid the less will the joints open, on account of the shrinkage being distributed over a greater number of joints.

The floor boards may be nailed at their edges, rebated, grooved and tongued or dowelled, if it be wished to make a very perfect floor. Dowelling is superior to grooving and tonguing, because the cutting away the stuff to receive the tongue greatly weakens the edges of the joint, which are apt to curl.

224. Glue is an article of great importance to the joiner ; the strength of his work depending much upon its adhesive properties.

The best glue is made from the *skins* of animals ; that from the *sinewy* or *horny* parts being of inferior quality. The strength of the glue increases with the age of the animals from which the skins are taken.

225. Joiners' work is measured by the superficial or lineal foot, according to its description.

Floors by the square of 100 superficial feet.

Handrails, small mouldings, water-trunks, and similar articles, per lineal foot.

Cantilevers, trusses, cut brackets, scrolls to handrails, &c., are valued per piece.

The wages of a joiner are from 6*s.* to 7*s.* 6*d.* per day.

The following memoranda relative to carpenters' and joiners' work may be found useful.

Weight of Timber.

34	cubic feet of	mahogany	weigh	one ton
39	,,	oak	,,	,,
45	,,	ash	,,	,,
51	,,	beech	,,	,,
60	,,	elm	,,	,,
65	,,	fir	,,	,,

50 cubic feet of timber 1 load.

120 deals = one hundred.

120 12 ft. 3 in. deals = $5\frac{2}{5}$ loads of timber.

400 superficial feet $1\frac{1}{2}$ in. deal = 1 load.

Planks are	11 in. wide.
Deals	9 ,,
Battens	7 ,,

A reduced deal is $1\frac{1}{2}$ in. thick, 11 in. wide, and 12 feet long.

A square of flooring laid with 12 feet deals requires

Laid rough	$12\frac{1}{4}$ floorboards
Ditto, edges shot	$12\frac{1}{2}$,,
Wrought and laid folding . . .	13 ,,
Ditto, straight joint	$13\frac{1}{2}$,,
Wrought and laid straight joint, and ploughed and tongued . . .	14 ,,
If laid with 12 ft. battens,	
Wrought, and laid folding . . .	17 ,,
Ditto, ditto, straight joint	18 ,,

226. *Ironmongery* is charged for with the work to which it is attached; the joiner being allowed 10 per cent. profit upon the prime cost.

The principal articles of ironmongery used in a building consist of *nails* and *screws*, *sash pullies*, *bolts*, *hinges*, *locks*, *latches*, and *sash* and *shutter furniture*, besides a great variety of miscellaneous articles, which we have not space to enumerate.

227. Of the different kinds of hinges may be mentioned *hook* and *eye hinges*, for gates, coach-house doors, &c.; *butts* and *back-flaps*, for doors and shutters; *cross garnets* of ⊢ form, which are used for hanging ledged doors, and other inferior work: **H** and **H—** hinges, whose name is derived from their shape; and *parliament* hinges.

Besides these are used *rising butts*, for hanging doors to rise over a carpet, or other impediment: *projecting butts*, used when some projection has to be cleared, and *spring hinges* and *swing centres*, for self-shutting doors.

228. The variety of locks now manufactured is almost infinite. We may mention the *stock lock*, cased in wood, for common work. *Rim locks*, which have a metal case or rim, and are attached to one side of a door; they should not be used when a door has sufficient thickness to allow of a mortise lock, as they often catch the dresses of persons passing through the doorway. *Mortise locks*, as the name implies, are those which are mortised into the thickness of the door.

The handles and escutcheons are called the *furniture* of a lock, and are made of a great variety of materials, as brass, bronze, ebony, ivory, glass, &c.

229. Of latches, there are the common *thumb latch*, the *bow latch*, with brass knobs, the brass *pulpit latch*, and the *mortise latch*.

230. The *sawyer* is to the carpenter and joiner what the stone-cutter is to the mason.

The *pit-saw* is a large two-handed saw fixed in a frame,

and moved up and down in a vertical direction by two men called the top-man and the pit-man; the first of whom stands on the timber that is to be cut, the other at the bottom of the saw-pit. The timber is *lined out* with a chalk line on its upper surface, and the accuracy of the work depends mainly on the top-man keeping the saw to the line, whence the proverbial expression *top-sawyer*, meaning one who directs any undertaking.

In sawing up deals and battens into thicknesses for the joiner's use, the parallelism of the cuts is of the utmost importance, as the operation of *taking out of winding* a piece of uneven stuff, causes a considerable waste of material, and much loss of time.

Circular saws, moved by steam power, are now much used in large establishments, timber yards, &c., and effect a great saving of labour over the use of the pit saw, where the timbers to be cut are not too heavy to be easily handled. The saw is mounted in the middle of a stout bench, furnished with guides, by means of which the stuff to be cut is kept in the required direction, whilst it is pushed against the saw, which is the whole of the manual labour required in the operation.

SLATER.

231. The business of the slater consists chiefly in covering the roofs of houses with slates, but it has of late years been very much extended by the general introduction of sawn slate, as a material for shelves, cisterns, baths, chimney pieces, and even for ornamental purposes.

We purpose here to describe only those operations of the slater which have reference to the covering of roofs.

232. Besides the tools which are in common use among other artificers, the slater uses one peculiar to his trade,

called the *zax*, which is a kind of hatchet, with a sharp point at the back. It is used for trimming slates, and making the holes by which they are nailed in their places.

233. Slates are laid either on boarding or on narrow battens, from 2 to 3 inches wide, the latter being the more common method, on account of its being less expensive than the other.

The nails used should be either copper or zinc; iron nails though sometimes used, being objectionable from their liability to rust.

Every slate should be fastened with two nails, except in the most inferior work.

The upper surface of a slate is called its *back*, the under surface the *bed*, the lower edge the *tail*, the upper edge the *head*. The part of each course of slates exposed to view is called the *margin* of the course, and the width of the margin is called the *gauge*.

The *bond* or *lap* is the distance which the lower edge of any course overlaps the slates of the second course below.

In preparing slates for use, the sides and bottom edges are trimmed, and the nail-holes punched as near the head as can be done, without risk of breaking the slate, and at a uniform distance from the tail.

The lap having been decided upon the guage will be one half of the length of the slate, after the amount of the lap has been subtracted. Thus a countess slate (20 in. × 10 in.) laid to a 3 in. lap will show a margin of $8\frac{1}{2}$ in.

$$\frac{20 \text{ in.} - 3 \text{ in.}}{2} = \frac{17}{2} = 8\tfrac{1}{2} \text{ in.}$$ (*See* Figs. 99, 100.)

The battens are of course nailed on the rafters at the gauge to which the slates will work. If the slates are of

different lengths, they must be sorted into sizes, and gauged accordingly, the smallest sizes being placed nearest the ridge. The lap should not be less than 2 in., and need not exceed 3 in.

It is essential to the soundness as well as the appearance of slaters' work, that the slates should all be of the same width, and the edges perfectly true.

The Welsh slates are lightest and cheapest, and are of a light and dark blue colour. The Westmoreland slates are of a dull greenish hue, and heavy and expensive.

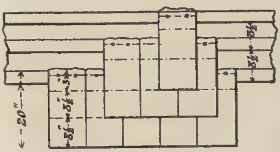


Fig. 99.

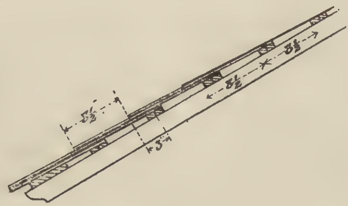


Fig. 100.

The copper nails should weigh from 5 to 8 lbs. per thousand.

234. Slaters' work is measured by the square of 100 superficial feet, allowances being made for the trouble of cutting the slates at the hips, eaves, round chimneys &c.

Slabs for cisterns, baths, shelves, and other sawn work, are charged per superficial foot, according to the thickness of the slab, and the labour bestowed on the work.

Rubbed edges, grooves, &c., are charged per lineal foot.

Table of the Sizes of Roofing Slates.

Description.	Size. Length.	Size. Brdth.	Average gauge in inches.	No. of squares 1200 will cover laid to 3 in. lap.	Weight per 1200 in tons.	No. required to cover one square, 3 in. lap.	No. of nails required to one square.
	ft. in.	ft. in.					
Doubles . . .	1 1	0 6	5	$2\frac{1}{2}$	$\frac{3}{4}$	480	960
Ladies . . .	1 4	0 8	$6\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{4}$	280	560
Countesses . .	1 8	0 10	$8\frac{1}{2}$	7	2	176	352
Duchesses . .	2 0	1 0	$10\frac{1}{2}$	10	3	127	254
Imperials . .	2 6	2 0	a ton will cover $2\frac{1}{4}$ to $2\frac{1}{2}$ squares.				
Rags and Queens	3 0	2 0					
Westmorelands, of various sizes			do. do. 2 to $2\frac{1}{2}$ do.				

Inch slab per foot superficial weighs 14 lbs.

A journeyman slater receives about 6*s.* 6*d.* per day, and his labourer about 4*s.* 6*d.*

PLASTERER.

235. The work of the plasterer consists in covering the brickwork and naked timbers of walls, ceilings, and partitions with plaster, to prepare them for painting, papering, or distempering; and in forming cornices, and such decorative portions of the finishings of buildings as may be required to be executed in plaster or cement.

236. The plasterer uses a variety of tools, of which the following are the principal ones:—

The *drag* is a three-pronged rake, used to mix the hair with the mortar in preparing coarse stuff.

The *hawk* is a small square board for holding stuff on, with a short handle on the under side.

Trowels are of two kinds, the *laying and smoothing tool*

with which the first and the last coats are laid, and the, *gauging trowel*, used for gauging fine stuff for cornices, &c., these are made of various sizes, from 3 to 7 in. long.

Of *floats*, which are used in *floating*, there are three kinds, viz, the *Derby*, which is a rule of such length as to require two men to use it ; the *hand float*, which is used in finishing stucco ; and the *quirk float*, which is used in floating angles.

Moulds, for running cornices, are made of sheet copper, cut to the profile of the moulding to be formed, and fixed in a wooden frame.

Stopping and *picking out tools* are made of steel, 7 or 8 in. long, and of various sizes. They are used for modelling, and for finishing mitres and returns to cornices.

237. *Materials.—Coarse stuff*, or lime and hair, as it is usually called, is similar to common mortar, with the addition of clean long hair from the tanner's yard, which is thoroughly mixed with the mortar by means of the drag.

Fine stuff is made of pure lime, slaked with a small quantity of water, after which, sufficient water is added to bring it to the consistence of cream.

It is then allowed to settle, and the superfluous water being poured off, it is left in a binn or tub to remain in a semifluid state until the evaporation of the water has brought it to a proper thickness for use. In using fine stuff for setting ceilings, a small portion of white hair is mixed with it.

Stucco is made with fine stuff, and clean-washed sand. This is used for finishing work intended to be painted.

Gauged stuff is formed of fine stuff mixed with plaster of Paris, the proportion of plaster varying according to the rapidity with which the work is required to set. Gauged stuff is used for running cornices and mouldings.

Enrichments, such as pateras, centre flowers for ceilings, &c., are first modelled in clay, and afterwards cast of plaster of Paris in wax or plaster moulds. Fibrous plaster ornaments also are much used, and have the advantage of being very light, and being easily and securely fixed with screws.

The variety of compositions and cements made use of by the plasterer is very great. Roman cement and Portland cement are the principal ones used for coating buildings externally. Martin's Parian and Keene's cements are well adapted for all internal plastering where sharpness, hardness, and delicate finish are required.

238. *Operations of Plastering.*—When brickwork is plastered, the first coat is called *rendering.*

In plastering ceilings and partitions, the first operation is *lathing.* This is done with *single*, *one and a-half*, or *double* laths; these names denoting their respective thicknesses. Laths are either of oak or fir; if the former, wrought-iron nails are used, but cast-iron nails may be employed with the latter. The thickest laths are used for ceilings, as the strain on the laths is greater in a horizontal than in an upright position.

Pricking up is the first coat of plastering of coarse stuff upon laths; when completed, it is well scratched over with the end of a lath, to form a key for the next coat.

Laid work consists of a simple coat of coarse stuff over a wall or ceiling.

Two-coat work is a cheap description of plastering, in which the first coat is only roughed over with a broom, and afterwards *set* with fine stuff, or with gauged stuff in the better descriptions of work.

The laying on of the second coat of plastering is called *floating*, from its being *floated*, or brought to a plane surface with the float.

The operation of floating is performed by surrounding the surface to be floated with narrow strips of plastering called screeds, brought perfectly upright, or level, as the case may be, with the level or plumb-rule; thus, in preparing for floating a ceiling, nails are driven in at the angles, and along the sides, about 10 ft. apart, and carefully adjusted to a horizontal plane, by means of the level. Other nails are then adjusted exactly opposite to the first, at a distance of 7 or 8 in. from them. The space between each pair of nails is filled up with coarse stuff, and levelled with a hand float; this operation forms what are called *dots*. When the dots are sufficiently dry, the spaces between the dots are filled up flush with coarse stuff, and floated perfectly true with a floating rule; this operation forms a *screed*, and is continued until the ceiling is surrounded by one continuous screed, perfectly level throughout. Other screeds are then formed, to divide the work into bays about 8 ft. wide, which are successively filled up flush, and floated level with the screeds.

The screeds for floating walls are formed in exactly the same manner, except that they are adjusted with the plumb-rule instead of the level.

After the work has been brought to an even surface with the floating rule, it is gone over with the hand float, and a little soft stuff, to make good any deficiencies that may appear.

The operation of forming screeds and floating work which is not either vertical or horizontal, as a plaster floor laid with a fall, is analogous to that of taking the face of a stone out of winding with chisel-drafts and straight edges in stone-cutting; the principle being in each case to find three points in the same plane, from which to extend operations over the whole surface.

Setting.—When the floating is about half dry, the setting or finishing coat of fine stuff is laid on with the smoothing trowel, which is alternately wetted with a brush and worked over with the smoothing tool, until a fine surface is obtained.

Stucco is laid on with the largest trowel, and worked over with the hand float, the work being alternately sprinkled with water, and floated until it becomes hard and compact, after which it is finished by rubbing it over with a dry stock brush.

The water has the effect of hardening the face of the stucco, so that, after repeated sprinklings and trowelings, it becomes very hard, and smooth as glass.

239. The above remarks may be briefly summed up as follows: The commonest kind of work consists of only one coat, and is called *rendering*, on brickwork, and *laying*, if on laths. If a second coat be added, it becomes two-coat work, as *render-set*, or *lath lay* and *set*. When the work is floated, it becomes three-coat work, and is *render*, *float*, and *set*, for brickwork, and *lath*, *lay*, *float*, and *set*, for ceilings and partitions; ceilings being set with fine stuff, with a little white hair, and walls intended for paper with fine stuff and sand; stucco is used where the work is to be painted.

Rough stucco is a mode of finishing staircases, passages, &c., in imitation of stone. It is mixed with a large proportion of sand, and that of a coarser quality than troweled stucco, and is not smoothed, but left rough from the hand float, which is covered with a piece of felt, to raise the grit of the sand, to give the work the appearance of stone.

Rough cast is a mode of finishing outside work, by dash ing over the second coat of plastering, whilst quite wet, a

layer of rough-cast, composed of well-washed gravel, mixed up with pure lime and water, till the whole is in a semi-fluid state.

Pugging is lining the spaces between floor joists with coarse stuff, to prevent the passage of sound, or between two stories, and is done on laths or rough boarding.

In the midland districts of England, reeds are much used instead of laths, not only for ceilings and partitions, but for floors, which are formed with a thick layer of coarse gauged stuff upon reeds. Floors of this kind are extensively used about Nottingham; and, from the security against fire afforded by the absence of wooden floors, Nottingham houses are proverbially fire-proof.

240. Plasterer's work is measured by the superficial yard; cornices by the superficial foot; enrichments to cornices by the lineal foot; and centre flowers and other decorations at per piece.

MEMORANDA.

The wages of a journeyman plasterer are from 6*s.* to 7*s.* 6*d.* a day; those engaged in modelling and ornamental work will earn much more; a labourer receives from 3*s.* 9*d.* to 6*s.* 3*d.* a day, and a plasterer's boy about 1*s.*

Lathing.—One bundle of laths and 500 nails will cover 5 yards.

Rendering.—187½ yards require 1½ hundred of lime, 2 double loads of sand, and 5 bushels of hair.

Floating requires more labour, but only half as much material as rendering.

Setting.—375 yards require 1½ hundred of lime, and 5 bushels of hair.

Render set.—100 yards require 1½ hundred of lime, 1

double load of sand, and 4 bushels of hair.—Plasterer and labourer, six days each.

Lath, lay, and *set.*—130 yards of lath, lay, and set, require 1 load of laths, 10,000 nails, $2\frac{1}{2}$ hundred of lime, $1\frac{1}{2}$ double load of sand, and 7 bushels of hair.—Plasterer and labourer, eight days each.

Fifteen per cent. profit is allowed on all materials.

SMITH AND IRONFOUNDER.

241. The smith furnishes the various articles of wrought-iron work used in a building; as pileshoes, straps, screw-bolts, dog-irons, chimney bars, gratings, wrought-iron railing, and wrought-iron balustrades for staircases. Wrought iron is always preferable to cast iron as an ornamental material on account of the effect it gives compared with cast iron. The former looks light and genteel and the latter heavy and clumsy, but the greater expense of wrought iron is a consideration, although it is possible to get cheaply intricate castings in malleable cast iron, which is very clean and sharp and resembles wrought iron and can be welded to the other parts where wrought iron is essentially the material.

Cast iron cannot, whereas wrought iron or steel can, both be welded, *i.e.*, united under heat.

Besides cast-iron columns, stanchions, and similar articles which are cast to order, the founder supplies a great variety of articles which are kept in store for immediate use; as cast-iron gratings, balconies, rain-water pipes and guttering, air traps, coal plates, stoves, stable fittings, iron sashes, &c.

Steel, wrought and cast iron work are paid for by weight, except small articles kept in store for immediate use, which are valued per piece.

		lbs.
One cubic foot of cast iron weighs about		450
Ditto	wrought ,,	480
Ditto	steel ,,	490

242. The *coppersmith* provides and lays sheet copper for covering roofs; copper gutters and rain-water pipes; washing and brewing coppers; copper cramps and dowels for stonemasons' work; and all other copper work in a building; but the cost of the material in which he works prevents its general use, although copper is everlasting in wear, and, moreover, at all times worth its value. Sheet copper is paid for by the superficial foot, according to weight, and pipes and gutters per lineal foot; copper in dowels, bolts &c., at per pound.

243. *Warming apparatus*, *steam* and *gas fittings*, and similar kinds of work, are put up by the mechanical engineer, who also manufactures a great variety of articles, which are purchased in parts, and put together and fixed by the plumber, as pumps, taps, water closet apparatus, &c.

244. The *bell-hanger* provides and hangs the bells required for communicating between the different parts of a building, and connects them with their *pulls*, or handles, by means of cranks and wires.

The action of the pull upon the bell should be as direct, and effected with as few cranks, as possible; and the cranks and wires should be concealed from view, both to protect them from injury, and on account of their unsightly appearance.

In all superior work, the wires are conducted along concealed tubes, fixed to the walls before the plasterer's work is commenced. The simplest way of arranging the wires is to carry them up in separate tubes to the roof, where they may all be conducted to one point, and brought down a

chase in the walls to the part of the building where the bells are hung. By this means very few cranks are required, and a broken wire can be replaced at any time without trouble.

245. Bell-hangers' work is paid for by the number of bells hung; the price being determined by the manner in which the work is executed. The *furniture* to the pulls is charged in addition, at per piece. Electricity has now superseded the old-fashioned bells as described above. Two wires (a negative and positive) are laid in tubes, and by means of a push at the desired point, the two are brought together to create a current which rings a gong where required and indicates the room ringing the bell.

PLUMBER.

246. The work of the plumber chiefly consists in laying sheet lead on roofs, lining cisterns, laying on water to the different parts of a building, and fixing up pumps and water closets.

247. The plumber uses but few tools, and those are of a simple character, the greater number of them being similar to those used by other artificers, as *hammers*, *mallets*, *planes*, *chisels*, *gouges*, *files*, &c. The principal tool peculiar to the trade of the plumber is the *bat*, which is made of beech, about 18 inches long, and is used for dressing and flattening sheet lead. For soldering also the plumber uses iron ladles, of various sizes, for melting solder, and *grozing irons* for smoothing down the joints.

248. The sheet lead used by the plumber should always be *milled*, and it is described according to its weight.

4 lbs. lead being used for soakers.
5 ,, ,, flashings and aprons.

6 lbs. lead being used for vertical work and valleys.
7 „ „ gutters and flats.
8 „ „ hips and ridges.

Lead pipes, if of large diameter, are made of sheet lead, dressed round a wooden core, and soldered up.

Smaller pipes are cast in short lengths, of a thickness three or four times that of the intended pipe, and either *drawn* or *rolled* out to the proper thickness.

Soft solder is used for uniting the joints of lead-work. It is made of equal parts of lead and tin, and is purchased of the manufacturer by the plumber, at a price per lb. according to the state of the market.

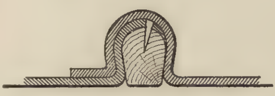


Fig. 101.

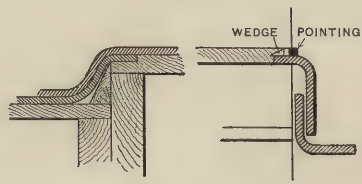


Fig. 102.

249. *Laying of Sheet Lead.*—In order to secure lead-work from the injurious effects of contraction and expansion, when exposed to the heat of the sun, the plumber is careful not to confine the metal by soldered joints, or otherwise. All sheet lead should be laid to a sufficient *current*, to keep it dry; a fall of 1 inch in 10 feet is sufficient for this purpose, if the boarding on which the lead is laid be perfectly even. Joints in the direction of the current are made by dressing the edges of the lead over a wooden *roll*, as shown in Fig. 101.

Joints in the length of the current are made with *drips*, as shown on the left-hand side of Fig. 102.

Flashings are pieces of lead *turned down* over the edges of other lead work, which is *turned up* against a wall, as shown on the right-hand side of Fig. 102, and serve to keep the wet from finding its way between the wall and the lead, whether of a flat or the soakers to each slate up a gable or chimney. The most secure way of fixing them is to build them into the joints of the brickwork; but the common method is to insert them about an inch into the mortar joint, and to secure them with wall hooks and cement. (*See* Fig. 102.)

250. A very important part of the business of the plumber consists in fitting up cisterns, pumps, and water-closet apparatus, and in laying the different services and wastes connected with the same.

251. Plumbers' work is paid for by the cwt., and lead pipes are charged per foot lineal, according to size and weight.

Pumps and water-closet apparatus are charged at so much each, according to description; as also basins, air traps, washers and plugs, spindle valves, stop-cocks, ball-cocks, &c.

Table of the weight of lead pipes required by most Water Companies.

	bore		lbs.	
not exceeding	$\frac{1}{2}$ inch	. . . .	7	Per yard.
,,	$\frac{5}{8}$,,	. . . .	9	
,,	$\frac{3}{4}$,,	. . . .	11	
,,	1 ,,	. . . .	16	
,,	$1\frac{1}{4}$,,	. . . .	22	

The wages of a journeyman plumber are from 6*s.* to 7*s.* 6*d.* a day. A plumber's labourer receives from 3*s.* 9*d.* to 5*s.* 3*d.* a day.

ZINC WORKER.

252. The use of sheet lead has been, to a certain extent, superseded by the use of sheet zinc, which, from its cheapness and lightness, is very extensively used for almost all purposes to which sheet lead is applied. It is, however, a very inferior material, and not to be depended upon. The laying of it is generally executed by the plumber; but the working of zinc, and manufacturing of it into gutters, rain-water pipes, chimney cowls, and other articles, is practised as a distinct business.

GLAZIER.

253. The business of the glazier consists in cutting glass, and fixing it into lead-work, or sashes. The former is the oldest description of glazing, and is still used, not only for cottage windows, and inferior work, but for church windows, and glazing with stained glass, which is cut into pieces of the required size, and set in a leaden framework; this kind of glazing is called *fretwork.*

254. *Glazing in sashes* is of comparatively modern introduction. The sash bars are formed with a *rebate* on the outside, for the reception of the glass, which is *cut into* the rebates, and firmly *bedded* and *backputtied* to keep it in its place. Large squares are also *sprigged,* or secured with small brads driven into the sash-bars.

255. *Glazing in lead-work* is fixed in leaden rods, called *cames,* prepared for the use of the glazier by being passed through a glazier's vice, in which they receive the grooves, for the insertion of the glass. The sides or cheeks of the grooves are sufficiently soft to allow of their being turned down to admit the glass, and again raised up and firmly pressed against it after its insertion.

For common lead-work, the bars are soldered together, so as to form squares or diamonds. In fretwork, the bars, instead of being used straight, are bent round to the shapes of the different pieces of glass forming the device—lead-work is strengthened by being attached to *saddle bars* of iron, or copper, by means of copper wire soldered to the lead. All glass should be cemented within the cames.

Putty is made of pounded whiting, beaten up with linseed oil into a tough tenacious cement.

256. The principal tool of the glazier is the *diamond*, which is used for cutting glass. This tool consists of an unpolished diamond fixed in lead, and fastened to a handle of hard wood.

The glazier uses a *hacking-out knife*, for cutting out old putty from broken squares; and the *stopping knife* for laying and smoothing the putty when *stopping-in* glass into sashes.

For setting glass into lead-work, the *setting knife* is used.

Besides the above, the glazier requires a square and straight edges, a rule, and a pair of compasses, for dividing the tables of glass to the required sizes.

Also a hammer and brushes, for sprigging large squares, and cleaning off the work.

The *glazier's vice* has already been mentioned; the *latterkin* is a pointed piece of hard wood, with which the grooves of the *cames* are cleared out and widened for receiving the glass.

257. Glazier's work is valued by the superficial foot, the price increasing with the size of the squares. Irregular panes are taken of the extreme dimensions each way.

258. Glass is made from a mixture of chalk, white sand, and soda, melted at a great heat, and *blown* into cylinders which are cut and flattened out on a table under heat.

There are several classes of glass described as Crown, sheet and plate, and there are several kinds and qualities of sheet and plate, the most generally used being :

Sheet glass distinguished by its weight per foot superficial as 16ozs., 21ozs., 26ozs., and 32ozs., and plate glass by its thickness from $\frac{1}{12}$-inch upwards, the relative value of sheet rising upwards from 16ozs., and plate being cheapest at $\frac{1}{4}$-inch thick and more expensive above and below that point.

Plate glass is cast, rolled, ground, and polished, being usually $\frac{1}{4}$-inch thick, but it can be reduced to $\frac{1}{12}$-inch thick and polished so that no better glass can be procured for the best dwellings.

Rough cast or rough rolled glass are obscure and used for skylights and positions where the rays of the sun require to be diffused.

PAINTER, PAPER-HANGER, AND DECORATOR.

259. The business of the house-painter consists in covering, with a preparation of white lead and oil, such portions of the joiner's, smith's, and plasterer's work as require to be protected from the action of the atmosphere. Decorative painting is a higher branch, requiring a knowledge of the harmony of colours, and more or less of artistic skill, according to the nature of the work to be executed. The introduction of fresco painting into this country as a mode of internal decoration has led to the employment of some of the first artists of the day in the embellishment of the mansions of the nobility ; and the example thus set will, no doubt, be extensively followed.

260. The principal materials used by the painter are *white lead,* which forms the basis of almost all the colours

used in house-painting; *linseed oil*, and *spirits of turpentine*, used for mixing and diluting the colours; and *dryers*, as litharge, sugar of lead, and white vitriol, which are mixed with the colours to facilitate their drying. *Putty*, made of whiting and linseed oil, is used for *stopping* or filling up nail holes, and other vacuities, in order to bring the work to a smooth surface.

261. The painter's tools are few and simple; they consist of the *grinding stone* and *muller*, for grinding colours; *earthen pots*, to hold colours; *cans*, for oil and turps; a *pallet knife*, and *brushes* of various sizes and descriptions.

262. In painting woodwork, the first operation consists in *killing* the knots, from which the turpentine would otherwise exude and spoil the work. To effect this, the knots are covered with fresh slaked lime, which dries up and burns out the turpentine. When this has been on twenty-four hours, it is scraped off, and the knots painted over with a mixture of red and white lead, mixed with glue size. After this they are gone over a second time with red and white lead, mixed with linseed oil. When dry, they must be rubbed perfectly smooth with pumice stone, and the work is ready to receive the priming coat. This is composed of red and white lead, well diluted with linseed oil. The nail holes and other imperfections are then stopped with putty, and the succeeding coats are laid on, the work being rubbed down between each coat, to bring it to an even surface. The first coat after the priming is mixed with linseed oil and a little turpentine; the second coat with equal quantities of linseed oil and turpentine. In laying on the second coat, where the work is not to be finished white, an approach must be made to the required colour. The third coat is usually the last, and is made with a base of white lead, mixed with the requisite colour,

and diluted with one-third of linseed oil to two-thirds of turpentine.

Painting on stucco, and all other work in which the surface is required to be without gloss, has an additional coat mixed with turpentine only, which, from its drying of one uniform *flat* tint, is called a flatting coat.

If the knots show through the second coat, they must be carefully covered with silver leaf.

Work finished as above described would be technically specified as knotted, primed, painted three-oils, and flatted.

Flatting is almost indispensable in all delicate interior work, but it is not suited to outside work, as it will not bear exposure to the weather.

263. Painting on stucco is primed with boiled linseed oil, and should then receive at least three coats of white lead and oil, and be finished with a flat tint. The great secret of success in painting stucco is, that the surface should be perfectly dry ; and, as this can hardly be the case in less than two years after the erection of a building, it will always be advisable to finish new work in distemper, which can be washed off whenever the walls are sufficiently dry to receive the permanent decorations.

264. *Graining* is the imitation of the grain of various kinds of woods, by means of *graining tools*, and, when well executed, and properly varnished, has a handsome appearance, and lasts many years. The term graining is also applied to the imitation of marbles.

265. Clear coling (from *claire colle*, i.e. transparent size, Fr.), is a substitution of size for oil, in the preparation of the priming coat. It is much resorted to by painters, on account of the ease with which a good face can be put on the work with fewer coats than when oil is used ; but it will not stand damp, which causes it to scale off, and it should

never be used except in repainting old work, which is greasy or smoky, and cannot be made to look well by any other means.

266. *Distempering* is a kind of painting in which whiting is used as the basis of the colours, the liquid medium being size; it is much used for ceilings and walls, and always will require two, and sometimes three coats, to give it a uniform appearance.

267. Of late years several valuable distempers have been put on the market, most of them being already mixed in colour are much better than the home-made coverings, and in addition they are washable and the colour does notrub off as soon as the wall is touched.

Duresco is a substitute for both paint and distemper, and makes excellent work on walls, ceilings, and woodwork. Varnish is a coating material applied to all first-class work to give it a durable glossy face, and it may be put on paint work, papering, or the naked work, after it has been sized to take up the undue suction.

The varnish generally used is called "copal," being made at the factories by mixing resin, oil, and turpentine at various temperatures.

268. Painters' work is valued per superficial yard, according to the number of coats, and the description of work, as common colours, fancy colours, party colours, &c.

Where work is cut in on both edges, it is taken by the lineal foot. In measuring railings, the two sides are measured as flat work. Sash frames are valued per piece, and sashes at per dozen squares.

269. Gilding is executed with gold leaf, which is furnished by the gold-beater in books of 25 leaves, each leaf measuring $3\frac{1}{8}$ in. by 3 in. The parts to be gilded are first

prepared with a coat of gold size, which is made of Oxford ochre and fat oil.

270. The operations of the paper-hanger are too simple to require description.

A piece of paper is 12 yards long, and is 20 in. wide when hung, and covers 60 feet superficial; hence the number of superficial feet that have to be covered, divided by 60, will give the number of pieces required, but the matching of a large pattern causes greater waste.

Paper-hangers' work is valued at per piece, according to the value of the paper.

The trades of the plumber, glazier, painter, paper-hanger, and decorator are often carried on by the same person.

SECTION V.

WORKING DRAWINGS, SPECIFICATIONS, ESTIMATES, AND CONTRACTS.

WORK OF THE ARCHITECT AND THE SURVEYOR.

271. The erection of buildings of any considerable magnitude is usually carried on under the superintendence of a professional architect, whose duties consist in the preparation of the various working drawings and specifications that may be required for the guidance of the builder; in the strict supervision of the work during its progress, to insure that his instructions are carried out in a satisfactory manner; and in the examination and revision of all the accounts connected with the works.

272. The duties of the architect and the work of the builder are sometimes attempted by the same person: but this union of directive and executive functions is not to be recommended, if only because the absence of professional control must always be a temptation to a building contractor to prefer his own interests to those of his employer.

Since about the beginning of the last century a new and most important profession has sprung up, occupying a middle position between those of architecture and mechanical engineering, viz., that of the civil engineer. The practice of the architect and of the civil engineer so closely approximate in many respects, that it is

difficult strictly to draw the line of demarcation between them; but it may be said in general terms that, whilst the one is chiefly engaged in works of civil and decorative architecture, such as the erection of churches, public buildings, and dwelling houses, the talent of the other is principally called forth in the art of construction on a large scale, as applied to retaining walls, bridges, tunnels, light-houses, &c., and works connected with the improvements of the navigation and internal communications of the country.

273. The business of the surveyor is often carried on as a distinct branch of architectural practice; and, as the title of surveyor is often appropriated by those who have no real claim to it, a few words on a surveyor's duties may not be here out of place.

Surveyors may be divided into three classes: land surveyors, engineering surveyors, and building surveyors.

The business of an engineering surveyor, as distinguished from that of a land surveyor, chiefly consists in the preparation of accurate plans, sections, and other data relative to the intended sites of large works, which may be required by the architect or engineer preparatory to making out his working drawings, and in conducting levelling operations for drainage works, canals, railways, &c.

The building surveyor prepares, from the drawings and specifications of the architect or the engineer, bills of quantities of intended works, for the use of the builder, on which to frame his estimates; and, in the case of contracts, these bills of quantities form the basis of the engagements entered into by the builder and his employer, the surveyor being pecuniarily answerable for any omissions. The surveyor is also employed in the measurement of works already executed or in progress; in the latter case, for the purpose

of ascertaining the advances to be made at stated intervals, and is engaged generally in all business connected with builders' accounts.*

274. The following is the general routine of proceedings in the case of large works. It will readily be understood that in small works subdivision of labour is not carried to such an extent, the architect superintending the works himself, without the aid of a clerk of the works, and the builders taking out their own quantities.

I. The general design having been approved of, and the site fixed upon, an exact plan is made of the ground, the nature of the foundation examined, and all the levels taken that may be required for the preparation of the working drawings.

II. The architect makes out the working drawings, and draws up the specification of the work.

III. A meeting is held of builders proposing to tender for the execution of the proposed works, called either by public advertisement or private invitation, at which a surveyor is appointed in their behalf to take out the quantities. Sometimes two surveyors are appointed, one on the part of the builders, and one on the part of the architect, who take out the quantities together, and check each other as they proceed.

IV. The surveyor having furnished each party proposing to tender, with a copy of the bills of quantities, the builders prepare their estimates, basing them on the quantities supplied to all alike, after which the successful competitor and the employer sign a contract, drawn up by a solicitor, binding the one to the proper execution of the works, and

* See "Student's Guide for Measuring and Estimating Artificer's Work," 2nd edition, 8vo, 1853.

the other to the payment of the amount of their cost at such times and in such sums as may be set forth in the specification.

V. The work is then set out,* and carried on under the constant direction of a foreman on the part of the builder,

* *On Setting-out Work.*—The determination of the extra position of an intended building being sometimes difficult to accomplish, a few remarks on the subject may be acceptable.

The setting-out of the leading lines is simple enough on level ground, where nothing occurs to interrupt the view, or to prevent the

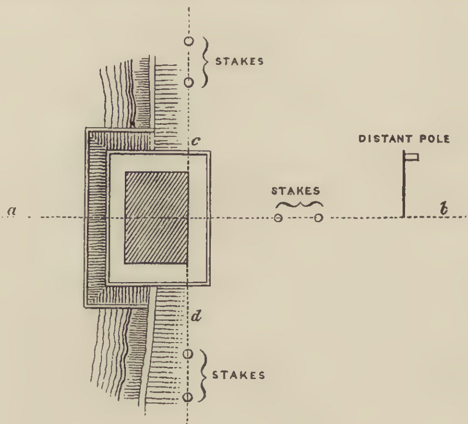


Fig. 103.

direct measurement of the required distances; but to perform this operation at the bottom of a foundation pit, blocked up with balks and shores, and ankle-deep in slush, requires a degree of practice and patience not always to be met with. Let us take a simple case, such as the putting in the abutment of a bridge or viaduct, any error in the position of which would render the work useless (see Fig. 103). The leading lines having been laid down on the drawings, the first thing to be done, before breaking ground, is to set out the centre line very carefully with a theodolite and ranging rods for a considerable distance on each side of the work, and to fix its position by erecting poles,

and on the part of the architect under the superintendence of an inspector or clerk of the works, whose duty is to be constantly on the spot to check the quality and quantity of material used, to see to the proper execution of the work, and to keep a record of every deviation from the drawings that may be rendered necessary by the wishes of the employer, or by local circumstances over which the architect has no control.

The work is measured up at regular intervals, and payments made on account to the builder, upon the architect's certificate of the amount of work done.

planed true and placed perfectly upright, in some part of the line where there is no chance of their being disturbed.

Next, the exact position of the abutment on the centre line would be decided upon, and fixed by setting out another line at right angles to the first, as $c\ d$, which would also be extended beyond the works, and its position fixed by driving in stakes, the exact position of the line on the head of the stake being marked by a saw-cut ⦶.

These guiding lines having now been permanently secured, the plan of the abutment may be set out on the ground, the dams driven, and the earth got out to the required depth. By the time the excavation is ready for commencing the work, it generally presents a forest of stays, struts, and shores, that would defy any attempt at setting out the work on its own level; it must, therefore, be set out at the level of the top of the dam, and the points transferred or *dropped*, as follows:—

First, the position of the centre line is ascertained by reference to the poles, and, nails being driven into the timbers at the sides of the dam, a fine line is strained across; the position of the line $c\ d$ is found, and a second line is strained across in the same way. In a similar manner other lines are strained from side to side at the required distances, the lengths being measured from the line $c\ d$, and the widths from $a\ b$, until the outline of the foundation course is found; the angle points are then transferred to the bottom of the excavation by means of plumb-lines, and the work is commenced, its accuracy being easily tested by measurements from the lines $a\ b$ and $c\ d$, until it is so far advanced as to render this unnecessary.

VI. The work being completed, the extras and omissions are set against each other, and the difference added to or deducted from the amount of the contract, and the whole business is concluded by the architect giving a final certificate for the payment of the balance due to the builder.

275. *Plan of Site.*—In preparing the plan of the site of any proposed works, the operations of the surveyor will generally have to be extended beyond the spot of ground on which the building is to stand. The frontages of the adjacent buildings, and the position of all existing or contemplated sewers, drains, and watercourses, should be correctly ascertained and laid down. Sketches drawn to scale of the architectural features of the adjacent buildings, if in town, and accurate outline sketches of the *incidents* of the locality of the intended operations, if in the country, should accompany the plan, that the architect may try the effect of his design before its actual execution renders it impossible to remedy its faults.

By the careful study of all these data the architect may hope to succeed in making his works harmonise with the objects that surround them; without them, failure on this head is almost a certainty.

276. *Levels.*—Where the irregularities of the ground are considerable, it is necessary to ascertain the variations of the surface before the depth of the foundations and the position of the floors can be decided upon.

It also frequently happens that the levels of the floors and other leading lines, in a new building, are regulated by the capabilities of sewage or drainage, or by the heights of other buildings with which the new work will ultimately be connected, as in the case of new streets. It therefore becomes of importance to have simple and accurate means

of ascertaining and recording the relative heights of different points. For this purpose both the spirit level and the mason's level are used.

277. Where the ground to be levelled over is limited in extent, and the variations of level do not exceed 12 feet, the heights of any points may be found with the mason's level in the following manner. (*See* Fig. 104).

In a convenient place, near the highest part of the ground, drive three stout stakes at equal distances from each other, and nail to them three pieces of stout plank, placed as shown in the cut, their upper edges being adjusted to the same horizontal plane by means of the mason's level.

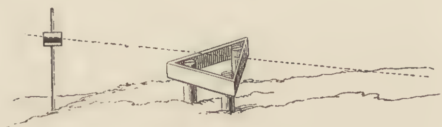


Fig. 104.

The level being then placed on this frame, an assistant proceeds to the first point of which the height is required, holding up a rod with a sliding vane, which he raises or lowers in obedience to the directions of the surveyor, until it coincides with a pair of sights fixed at the bottom of the level; the height of the vane will then be the difference of level between the top of the levelling frame, and the place where the staff was held up.

278. The above and similar methods will suffice for taking levels in a rough way for the ordinary purposes of the builder; but where great accuracy is requisite, or where the levels have to be extended over a considerable distance, as is often the case in drainage works, the use of a more

perfect contrivance is necessary, and the spirit level is the instrument principally used for this purpose.

The spirit level consists of a telescope mounted on a portable stand, and furnished with screw adjustments, by means of which it can be made to revolve in a horizontal plane, any deviation from which is indicated by the motion of an air-bubble in a glass tube fixed parallel to the telescope.

The eye-piece of the telescope is furnished with cross-wires, as they are technically termed, made of spiders' thread, of which the use will be presently explained.

279. The levelling staff, now in common use, is divided into feet, tenths, and hundredths, in a conspicuous manner, so that, with the help of the glass, every division can be distinctly seen at the distance of one hundred yards or more. The mode of conducting the operation of levelling is as follows:—

The surveyor having set up and adjusted his instrument, the staffholder proceeds to the point at which the levels are to commence, and holds up his staff perfectly upright and turned towards the surveyor, who notes the division of the staff which coincides with the horizontal wire in the telescope, and enters the same in his level-book; the staffholder then proceeds to the next point, and the reading of the staff is noted as before; and this is repeated until the distance or the difference of level makes it necessary for the surveyor to take up a fresh position. While this is being done, the staffholder remains stationary, until, the level being adjusted again, he carefully turns the face of the staff so as to be visible from the instrument in its new position, and a second reading of the staff is noted, after which he proceeds forward as before for a fresh set of observations.

280. In every set of observations the first is called a Backsight and the last a Foresight. The remaining observations are called intermediates, and are entered accordingly. It will be seen that an error in an intermediate reading is confined to the point where it occurs; but a mistake in a back or foresight is carried throughout the whole work, and therefore every care should be taken to insure accuracy in observing these sights.

281. The surveyor should commence and close his work by setting the staff on some well-defined mark, which can readily be referred to at any subsequent period, such as a doorstep, plinth of a column, &c. These marks are called bench marks, written B M, and are essential for either checking the work or carrying it on at a subsequent period.

282. The reduction of the levels to a tabular form for use is a simple arithmetical operation, which will be readily understood by examination of the annexed example of a level-book, and of the accompanying section,* Fig. 105. The difference between the successive readings in any set of observations is the difference of level between the points where the staff was successively held up, and by simple addition or subtraction, according as the ground rises or falls, we might obtain the total rise or fall of the ground above or below the starting point; but as this would require two columns, one for the total rise, and one for the total fall, it is simpler to assume the starting point to be some given height above an imaginary horizontal *datum line*, drawn below the lowest point of the ground, to which level

* In plotting sections of ground, it is usual to make the vertical scale much greater than the horizontal, which enables small variations of level to be easily measured on the drawing without its being extended to an inconvenient length. This is shown in the lower half of Fig. 105. The upper part of the figure shows the section plotted to the same horizontal and vertical scale.

all the heights are referred in the column headed total height above datum line.

283. The accuracy of the arithmetical computations is proved by adding up the foresight and backsights, and, deducting the sum of the former from that of the latter (the height of the first B M having been previously entered at the top of the page as a backsight), the remainder will be the height of the last B M, and should agree with the last figures in the column of total heights.

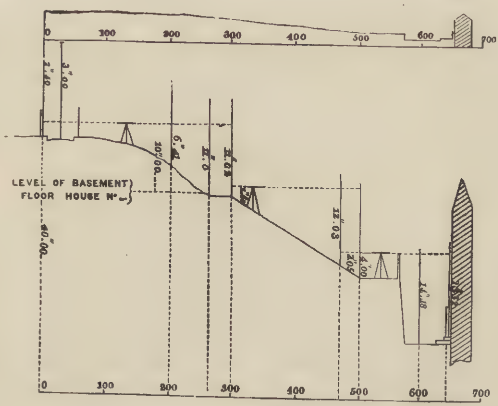


Fig. 105.

284. In levelling the site of a proposed building, if no suitable object presents itself for a permanent B M for future reference, a large stake, hooped with iron, should be driven into the ground in some convenient place where it will not be disturbed. The height of this stake being then carefully noted and marked upon the elevations and sections of the building, it will serve as a constant check on the depths of the excavations and the heights of the

different parts of the work, until the walls reach the level of the principal floor, when it will no longer be required.

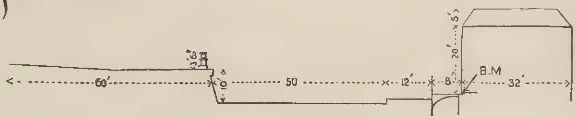
285. We must not leave the subject of levels without mentioning a very useful instrument, called the water-level, which consists of a long flexible pipe, filled with water, and terminating at each end in an open glass tube. When it is required to find the relative heights of any two points, as, for instance, the relative levels of the floors of two adjoining houses, the two ends of the tube are taken to the respective points, the tube being passed down the staircases, over the roofs, or along any other accessible route, no matter how circuitous, and the required levels are found by measuring up from the floors to the surface of the water, which will of course stand at the same level at each end of the tube.

WORKING DRAWINGS.

286. The architect being furnished with the plan and levels of the site of his operations, and having caused a careful examination to be made of the probable nature of the foundation by digging pits or taking borings, proceeds to make out his working drawings.

It is not sufficient for the execution of working drawings that the draughtsman should be acquainted with the ordinary principles of geometrical projection. He must also be thoroughly conversant with perspective, and with the principles of chiaroscuro, or light and shade, or he will work at random, as the geometrical projections which are required for the use of the workmen give a very false idea of the effect the work will have in execution.

287. Working drawings may be divided under three

Readings of the Staff.			Difference of readings.		Reduced levels.	Distance in feet.	Remarks.
Back sight.	Inter-mediate	Fore sight.	Rise.	Fall.	Total height above datum line.		Levels of Building Ground at—— (Date).
40.00	Height of 1st B M above datum.						
2.50	..	..	..	0.50	40.00	—	B M on doorstep of garden, No. — Park Road.
	3.00	..	..	7.00	39.50	30	On centre of Park Road. 
	10.00	..	..	1.00	32.50	..	Level of basement floor at No. — * * * Terrace.
	11.00	..	..	0.02	31.50	260	Terrace walk.
1.60		11.02	..	10.43	31.48	300	
2.05		12.03	..	1.95	21.05	475	
	4.00	..	..	10.18	19.10	500	
	14.18	..	0.86	..	8.92	600	Centre of Lower Road.
		13.02			9.78	..	B M top of doorstep, No. — Lower Road.
46.15		36.37					
36.37							
9.78	Reduced level of last B M.						

heads, viz. :—Block plans, General drawings, and Detail drawings :—

I. *Block Plans.*—These show the outline only of the intended building, and its position with regard to surrounding objects. They are drawn to a small scale, embracing the whole area of the site, and on them are marked the existing boundary walls, sewers, gas and water mains, and all the new walls, drains, and water-pipes, and their proposed connection with the existing ones, so that the builder may see at a glance the extent of his operations.

A well-digested block plan, with its accompanying levels showing the heights of the principal points, the fall of the drains, &c., is one of the first requisites in a complete set of working drawings.

II. *General Drawings.*—These show the whole extent of the building, and the arrangement and connection of the different parts more or less in detail, according to its size and extent. These drawings consist of *Plans* of the foundations, and of the different stories of the building, and of the roofs; *Elevations* of the different fronts; and *Sections* showing the heights of the stories, and such constructive details as the scale will admit of. These drawings are carefully figured, the dimensions of each part being calculated, and its position fixed by reference to some well-defined line in the plans or elevations, the position of which admits of easy verification in all stages of the work. This is best done by ruling faint lines on the drawings, through the principal divisions of the design, as shown in Fig. 106, where the plan and elevation are divided into compartments by lines passing through the centres of the columns from which all the dimensions are dated each way. These centre lines are, in the execution of the work, kept con-

stantly marked on the walls as they are carried up, so that they are at all times available for reference.

By this means, the centre lines having been once carefully marked on the building, any slight error or variation from the drawings is confined to the spot where it occurs instead of being carried forward, as is sometimes the case, to appear only when correction is as desirable as it is impossible.

The use of these centre lines also saves much of the

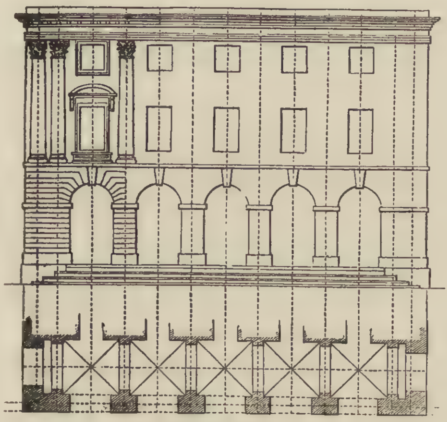


Fig. 106.

labour of the draughtsman, as they form a skeleton, of which only so much need be filled up as may be required to show the design of the work.

III. *Detailed Drawings.*—These are on a large scale, showing those details of construction which could not be explained in the general drawings, such as the framing of floors, partitions, and roofs, for the use of the carpenter; the patterns of cast-iron girders and story posts for the

iron-founder ; decorative details of columns, entablatures, and cornices, for the carver ; the requisite details being made out separately, as far as possible, for each trade ; which arrangement saves much time that would otherwise be wasted in referring from one drawing to another, and, which is still more important, insures greater accuracy, from the workman understanding better the nature of his work.

In making the detailed drawings, every particular should be enumerated that may be required for a perfect understanding of the nature and extent of the work. Thus, in preparing the drawings for the iron-founder, every separate pattern should be drawn out, and the number stated that will be required of each.

This principle should be attended to throughout the whole of the detailed drawings, as, in the absence of such data, it is very difficult to prepare correct estimates for the execution of the work without devoting more time to the study of the drawings than can generally be obtained for that purpose.

SPECIFICATIONS.

288. The drawings being completed, the architect next draws up the specification of the intended works. This is divided under two principal heads—1st, the conditions of the contract; and 2nd, the description of the work.

The title briefly states the nature and extent of the works to be performed, and enumerates the drawings which are to accompany and to form part of the written specification.

289. *Conditions of Contract.*—Besides the special clauses and provisions which are required by the particular circumstances of each case, the following clauses are inserted in all specifications :—

1. The works are to be executed to the full intent and meaning of the drawings and specification, and to the satisfaction of the architect.

2. The contractor to take the entire charge of the works during their progress, and to be responsible for all losses and accidents until their completion.

3. The architect is to have power to reject all improper materials or defective workmanship, and to have full control over the execution of the works, and free access at all times to the workshops of the contractor where any work is being prepared.

4. Alterations in the design are not to vitiate the contract, but all extra or omitted works are to be measured and valued according to a schedule of prices previously agreed upon.

5. The amount of the contract to be paid by instalments as the works proceed, at the rate of — per cent. on the amount of work done, and the balance within ——— from the date of the architect's final certificate.

Lastly. The works are to be completed within a stated time, under penalties which are enumerated.

290. *The description of the works* details minutely the quality of the materials, and describes the manner in which every portion of the work is to be executed, the fulness of the description depending on the amount of detailed information conveyed by the working drawings, care being taken that the drawings and specification should, together, contain every particular that is necessary to be known in order to make a fair estimate of the value of the work.

291. The chief merit of a specification consists in the use of clear and explicit language, and in the systematic arrangement of its contents, so that the description of each

portion of the work shall be found in its proper place ; to facilitate reference, every clause should be numbered and have a marginal reference attached, and a copious index should accompany the whole.

BILLS OF QUANTITIES.

292. The surveyor being furnished by the architect with the drawings and specification, proceeds to take out the quantities for the use of the parties who propose to tender for the execution of the work. This is done in the same way that work is measured when executed, except that the measurements are made on the drawings with a scale instead of on the real building with measuring rods.

293. In taking out quantities there are three distinct operations : 1st, taking the dimensions of the several parts of the work and entering them in the dimension book ; 2ndly, working out the quantities from the dimensions, and posting them into the columns of the abstracts, which is called *abstracting ;* 3rdly, casting up the columns of the abstract and bringing the quantities into bill.

294. The dimension book is ruled and the dimensions entered as in the following examples :—

No.	Dimension.	Quantity.	Description.
	ft. in.	ft. in.	
16	14 0 0 $2\frac{1}{2}$ 0 10	38 10	Memel fir framed joists to front room ground floor.

In this example, the work measured consists of sixteen joists, each 14 ft. long and 10 in. deep and $2\frac{1}{2}$ in. thick, and the total quantity of timber they contain amounts to

38 ft. 10 in. cube. In putting down the dimensions, the length should be 1st, width next, and height or depth last.

Dimension.	No. of bricks in thickness.	Quantity.	Description.
ft. ins.		ft. in.	
20 6	$2\frac{1}{2}$	235 9	Stock brickwork in mortar to front wall, from footings to 1st set-off.
11 6			

This example needs no explanation.

295. In preparing the abstract for each trade, the surveyor looks over his dimensions to see what articles he will have, and rules his paper into columns accordingly, writing the proper heads over each.

The principal point to be attended to in abstracting quantities is, to preserve a regular rotation in arranging the different descriptions of work, so that every article may at once be found on referring to its proper place in the abstract.

No fixed rules can be given on this head, as the form of abstract is different for every trade, and must be varied according to circumstances; but, as a general principle, articles of least value should be placed first. Solid measure should take precedence of superficial, and superficial of lineal, and miscellaneous articles should come last of all; or in technical terms, the rotation should be, 1st, cubes; 2nd, supers.; 3rd, runs; and lastly, miscellaneous.

296. In bringing the quantities into bill, the same rotation is to be observed as in abstracting them, care being taken that every article is inserted in its proper place, so that it may readily be found in the bill.

BUILDERS' ESTIMATE.

297. The limits of this volume prevent our going into much detail on the subject of builders' accounts, and we mnst therefore confine ourselves to laying before the reader a skeleton estimate, which will give him a tolerable idea of the manner in which the several kinds of artificers' work are abstracted and brought into bill.

Estimate for the Erection of——at——for——, according to Specification and Drawings numbered 1 *to* —, *prepared by* —— *Architect.*

			£	s.	d.
	FOUNDATIONS.				
yds. ft.					
— — cube	Excavation to foundations (including cofferdams, pumping, &c.) . .	at —	—	—	—
— — ,,	Concrete	,, —	—	—	—
ft. in.					
— — ,,	Timber in piles driven — ft. through (describe the material), including ringing, shoeing, and driving, but not ironwork	,, —	—	—	—
— — ,,	Do. in 6-in. planking, spiked to pile-heads	,, —	—	—	—
cwt. qrs. lbs.					
— — —	Wrought iron in shoes to piles .	,, —	—	—	—
	Total of foundations to be carried to summary	£	—	—	—
	BRICKLAYER.		£	s.	d.
rods. ft.					
— — supl.	Reduced brickwork in mortar .	,, —	—	—	—
— — ,,	Do. do. in cement .	,, —	—	—	—
sqrs. ft.					
— — ,,	Tiling (describing the kind, whether plain or pantiling, if single or double laths, &c., &c.) . . .	,, —	—	—	—
yds. ft.					
— — ,,	Bricknogging to partitions . .	,, —	—	—	—
— — ,,	Paving (of various descriptions) .	,, —	—	—	—
	And all other articles valued per yard superficial				
ft. in.					
— — ,,	Gauged arches	,, —	—	—	—
— — ,,	Facings (with superior description of bricks, specifying the quality) .	,, —	—	—	—
	Carried forward . . .	£	—	—	—

BRICKLAYER *continued.*

			£ s. d.
ft. in.	Brought forward . .		— — —
— — cube	Cutting to arches or splays . . And all other work valued by the foot superficial.	at —	— — —
— — run	Barrel or other drains (specifying size, &c.)	,, —	— — —
— — ,,	Tile creasing . . . . . And all other articles valued by running measure.	,, —	— — —
Nos.	Chimney pots, each; bedding and pointing sash and door frames, each; and all miscellaneous articles		— — —
	Total of bricklayers' work to be carried to summary . . .	£	— — —

MASON.

			£ s. d.
yds. ft.			
— — cube	Rubble walling	,, —	— — —
— — ,,	Hammer-dressed walling in random courses	,, —	— — —
ft. in.			
— — ,,	Stone (describing the kinds) . .	,, —	— — —
— — supl.	Labour on above (as plain work, sunk, moulded, or circular work) .	,, —	— — —
— — ,,	Hearths, pavings, landings, &c., beginning with the thinnest .	,, —	— — —
— — ,,	Marble slabs, beginning with the thinnest and inferior qualities .	,, —	— — —
— — run	Window sills, curbs, steps, copings, &c.		
— — ,,	Joggle joints, chases, &c. . .	,, —	— — —
Nos.	Mortices and rail holes, &c.—dowels, cramps, and other articles numbered		
	Total of mason's work to be carried to summary	£	— — —

CARPENTER AND JOINER.

			£ s. d.
sqrs. ft.			
*— — supl.	Labour and nails to roofs, floors, or quarter partitions. . . .	,, —	— — —
— — ,,	Battenings and boardings according to description	,, —	— — —
*— — ,,	Floors, according to description, beginning with the inferior and ending with the best descriptions.	,, —	— — —
	And so on for all work valued by the square.		

Carried forward . . . £ — — —

	Carpenter and Joiner *continued.*		£ s. d.
ft. in.	Brought forward . .		— — —
*— — cube	Memel fir, according to description, as fir bond, fir framed, wrought and framed, wrought, framed, and rebated, &c.	at —	— — —
— — ,,	Do. proper door and window cases .	,, —	— — —
	Then oak and superior descriptions of timber, in the same way.		
	Then the superficial work, as—		
— — supl.	½-in. deal rough linings, and so on with the different thicknesses of deals according to the labour on them; arranging them according to their thickness and the amount of labour on them, beginning with the thinnest	,, —	— — —
	Then oak plank or mahogany in the same way.		
	Then take the framed work, as—		
— — ,,	1¼-in deal square-framed inclosure to closets, and so on with the rest of the framed work, as doors, shutters, sashes, frames, &c., according to description . .	,, —	— — —
	Then the work valued by running measure, as—		
— — run	2¼ Spanish mahogany moulded, grooved, and beaded handrail .	,, —	— — —
	Then the numbers, as—		
Nos.	Mitred and turned caps, fixing iron balusters, &c.	,, —	— — —
	Lastly.—The Ironmongery, every article of which should be carefully described	,, —	— — —
	Total of carpenter and joiner's work to be carried to summary	£	— — —

	Slater.		£ s. d.
sqrs. ft. — — supl.	Countess, or any other kind of slating, according to description .	,, —	— — —
	Carried forward		£ — — —

* In London, this work would be taken "cube," to include material and labour according to description. In the North it would be taken in "squares super." to include material and labour according to size and description.

	SLATER *continued.*		£ s. d.
	Brought forward . .		— — —
sqrs. ft. — — supl.	Then slate slab, as— Inch shelves, rubbed one side, beginning with the slabs of least thickness, and arranging them according to the labour bestowed on them	at —	— — —
— — run	Then the work valued by running measure, as— Patent saddle-cut slate ridge . .	„ —	— — —
Nos.	Lastly the numbers, as— Holes, cut, &c.	„ —	— — —
	Total of slater's work to be carried to summary	£	— — —

	PLASTERER.		£ s. d.
yds. ft. — — supl.	First the superficial quantity of plastering, as— Render float and set to walls, beginning with the commonest, and proceeding through the different descriptions of two and three coat work up to the stuccos and superior work	„ —	— — —
	Then the whitewashing, distempering, &c.	„ —	— — —
ft. in. — — run	Next the run of cornices, architraves, reveals, &c., as— Plain cornice to drawing-room, 14-in. girt	„ —	— — —
Nos.	And lastly the numbers, as— 4 mitres, 1 centre flower, 30-in. diameter, &c., &c. . . .		— — —
	Total of plasterer's work to be carried to summary . . .	£	— — —

	SMITH AND IRON-FOUNDER.		£ s. d.
tons.cwt.qrs.lbs — — — —	Begin with the cast-iron, as— Cast iron in No. 4 girders, including patterns, painting and fixing .	„ —	— — —
	N.B.—State the No. of patterns. Then the smaller castings, as— Railings, balconies, columns, &c. .	„ —	— — —
— — — —	Then the wrought iron, as— Wrought iron in chimney bars, straps, screw bolts, railings, &c. .	„ —	— — —
	Carried forward	£	— — —

	Smith and Iron-Founder *continued.*		£ s. d.
	Brought forward . .		— — —
yds. ft.	Then the articles sold by running measure, as—		
— — run	Cast-iron gutters, water-pipes, &c.	at —	— — —
	Lastly the numbers, as—		
Nos.	Stoves, coal-plates, stable-fittings, &c.		— — —
	Total smith and iron-founder's work to be carried to summary	£	— — —
	Bell-hanger.		
	Number the bells, and describe the mode of hanging, as—		£ s. d.
Nos.	— bells hung with copper wires in concealed tin tubes, with bells, cranks, and wires complete . .	,, —	— — —
	And then enumerate the ornamental furniture to the different pulls .	,, —	— — —
	Total of bell-hanger's work to be carried to summary . . .	£	— — —
cwt. qrs. lbs.	**Plumber.**		£ s. d.
— — —	Cast lead laid in gutters, hips, ridges, flats, cisterns, &c.; including all solder, wall hooks, nails, &c.	,, —	— — —
— — —	Milled do. do. . .	,, —	— — —
ft. in.	Then socket, rain-water, and funnel pipes, and other work valued by the lineal foot, as—		
— — run	Inch drawn pipes	,, —	— — —
	Lastly the numbers, as—		
Nos.	Joints, plugs, and washers, air traps, brass grates, cocks, copper balls, pumps, water closets, apparatus, &c.		
	Total of plumber's work to be carried to summary . . .	£	— — —
yds. ft.	**Painter.**		£ s. d.
— — supl.	Of painting, according to description, specifying the number of oils, and whether common or extra colours, beginning with the work in fewest coats and finishing with the most expensive descriptions .	,, —	— — —
	Carried forward . . .	£	— — —

PAINTER *continued.*

			£ s. d.
	Brought forward . .		— — —
ft. in.	Then the running work, as—		
— — run	Skirtings, plinths, window sills, &c.	at —	— — —
	Lastly the numbers, as—		
Nos.	Frames, squares, chimney pieces, &c.	,, —	— — —
	Total of painter's work to be carried to summary . . .	£	— — —

GLAZIER.

			£ s. d.
ft. in.			
— — supl.	Glazing, according to description, specifying size of squares and quality of glass	,, —	— — —
	Then the stained and other ornamental glass; and lastly, the plate glass.		
	Total of glazier's work to be carried to summary . . .	£	— — —

PAPER-HANGER AND DECORATOR.

			£ s. d.
yds. ft.			
— — supl.	Distempering according to description	,, —	— — —
ft. in.			
— — ,,	Scagliola slabs do. . .	,, —	— — —
yds. ft.			
— — run	Gold mouldings	,, —	— — —
Nos.	Pieces of paper hung, according to description, including preparing walls—Hanging, lining, paper, and pumicing do.	,, —	— — —
,,	Dozen of borders	,, —	— — —
	Total of paper-hanger and decorator's works to be carried to summary	£	— — —

SUNDRIES.

		£ s. d.
Temporary fencings—watching and lighting works		— — —
Office for clerk of works		— — —
District surveyor's fee		— — —
Fire insurance		— — —
Surveyor's charge for bills of quantities . .		— — —
Total sundries to be carried to summary . .	£	— — —

Carried forward . . . . £ — — —

		£ s. d.
Brought forward		— — —
Summary of Bills.		
Foundations		— — —
Bricklayer		— — —
Mason		— — —
Carpenter and joiner		— — —
Slater		— — —
Plasterer		— — —
Smith and iron-founder		— — —
Bell-hanger		— — —
Plumber, painter, and glazier		— — —
Paper-hanger and decorator		— — —
Sundries		— — —
Total amount of estimate	£	— — —

PROCEDURE IN ERECTION OF BUILDINGS.

298. The architect furnishes the builder, whose tender is accepted, with copies of the drawings from which the quantities have been taken off.

By reference to these, the builder can at all times satisfy himself that the detailed drawings, furnished for the execution of the work, contain nothing beyond what he has contracted for.

Copies of the drawings and specification are attached to the contract deed, and are signed by the builder and other parties respectively concerned.

299. It scarcely ever happens that a large undertaking can be carried into execution without considerable departure from the contract designs, especially in the matter of foundations and underground work; the exact nature and extent of which must often be uncertain until the works are commenced.

To provide for these contingencies without setting aside the contract, the builder's estimate is accompanied by a

schedule of prices at which he undertakes to execute any additional work that may be required, or to value any work that may be omitted. This schedule should be very carefully drawn out, so that there shall be no dispute as to its meaning ; thus, under the head of brickwork, it should be clearly understood whether centering is included in the price named, or whether it is to form an additional charge ; with iron-founder's work, whether the price includes patterns, and so on with every description of work.

300. For taking out quantities, surveyors are allowed a commission of $2\frac{1}{2}$ per cent. on the cost of the work, and they are responsible to the builder for any omissions which may have to be made good by the latter.

301. Architects are remunerated by a commission of 5 per cent. on the amount expended under their direction, besides travelling expenses, salary of the clerk of the works, and occasionally other charges, according to circumstances.

SECTION VI.

AN IDEAL DWELLING:

A FEW OF THE MOST IMPORTANT POINTS AND DETAILS NECESSARY TO ITS ATTAINMENT.

By J. P. ALLEN.

THE first proceeding of a person who purposes building a house to live in, is necessarily to select a site, and the points which will have to be borne in mind are (1) Aspect; (2) Surroundings; (3) Subsoil and Drainage; (4) Water and Lighting; and lastly (5) Accessibility.

Aspect.—The comfort and pleasure of living in the country are increased or diminished by the aspect selected, and it is important that a southerly or western front should be found for the reception and best rooms of a dwelling, because sunshine leads so much to the brightness and health of the inhabitants. Therefore it is advisable that the dining, drawing, and best bed-rooms should be placed fronting the sun, and the rooms for use in the early morning, such as the breakfast-room, may with advantage be faced to the east, while the domestic apartments and offices can be placed to the north and north-east. In fact it is better for pantries, larders, and stores to be situated where the temperature cannot be much varied by the rise and fall of the sun; and, furthermore, studies and libraries can with advantage be arranged to face the north, as the light in that quarter is much more regular.

Surroundings.—The position of the front and back entrances is, of course, regulated by the position of existing roads—the main entrance being from a main road, the back, tradesmen's, and stable entrances best approached from side or subsidiary roads and lanes.

The garden and conservatories should always be on the south and west, and naturally the site selected should have the picturesque and open views from that frontage.

Trees and plantations, where possible, should be to the east and north, because they form a protection from the cold blasts, rendering house and garden very snug, and the latter more successful and productive; but on the other hand, the trees, especially if lofty, should be at some distance from the house, as trees in the immediate vicinity of a house often are the cause of smoky chimneys.

Subsoil and Drainage.—These considerations are often closely identified, especially in rural localities, and are both of them very important in regard to health.

The best subsoil is gravel, and sand or rock are the next most suitable, clay of course being the last one viewed from an hygienic point, because of its coldness and subjection to the variations of temperature.

The adaptability of the contour of the ground for good and easy drainage is a desideratum, inasmuch as drains must have a sufficient fall wherever they go to, and the further the refuse of a dwelling can be taken the better.

In urban districts the drainage of a house can be discharged into the local sewers, by which it is carried away and disposed of in an efficient manner, and in such a case, provided the sewers and sewage disposal works are good, all that is necessary to the householder is to have his drainage system thoroughly trapped just before it enters the sewer; and his own system should thence be treated

with easy and gradual falls, not less than twelve inches per ten times the diameter of the pipe in feet (*i.e.* a 4-in. drain should have one foot fall in forty feet, and a 6-in. drain one foot fall in sixty feet), and the smaller the pipe the more thoroughly and completely the pipes themselves will be flushed. Every system or series of pipes should be well and periodically flushed by baths at the head of the run, or by adequate cisterns discharging automatically, and at every change of direction a spacious manhole should be placed. The sides and bottoms of these manholes should be most carefully constructed so that no solids can adhere and collect, and intermediately in the lengths of piping lamp-holes or inspection eyes should be placed so that stoppages may be traced and the efficiency of the drainage inspected. These and the manholes should be airtight, so that no noxious gases may be emitted, and all manhole covers should be embedded into the frames in tallow.

Furthermore, each system of piping should be thoroughly ventilated with an inlet at the lowest end, and an outlet of the same capacity discharging high up above the windows of the house; and every branch to sinks and other discharges from the dwelling should be efficiently trapped with a deep water-seal, which in dry weather should be periodically replenished with water, so as to counteract any evaporation.

In rural districts it is not always possible to run the drainage into sewers, and in such cases the owner must necessarily dispose of the refuse from his own house :—

(1) By a cesspool removed a considerable distance from the house and in the direction in which the prevailing winds would carry away any possible smells. The cesspools should be large enough not to require frequent emptying out, they should be ventilated at a height as before, and

be provided with an adequate overflow for the liquids discharging into a ditch or percolating through the soil, if it is not clay; and the drainage should be trapped efficiently to prevent gases, etc., ascending from the cesspools. Some authorities believe in making the cesspools airtight—the contention being that any microbes which might germinate would die for want of air.

(2) In case where cesspools are not desirable, the sewage can be disposed of by means of irrigation over or through the land, but such a system would only be a success where the ground lends itself to percolation—clay and rock would lead to failure.

Whether with the system of irrigation or cesspools, the same strictness relating to the drains should be enforced as pertains to the drains connected to a sewer, and all drains should be laid on and encased in cement concrete to prevent leakage due to settlements, etc.

Water and Lighting.—A good water supply is as important as good drainage, and wherever it is obtained from it should be analysed periodically to make sure that pure and wholesome water is being obtained, and that no contamination is taking place.

Urban, and occasionally rural districts, as a rule, are supplied under a general scheme sanctioned by the authorities, and in such cases the householder need have little trouble, but he should look for sufficient pressure and quantity at various points to be the better able to cope with fire, and it is always desirable, whether the source of supply be continuous or intermittent, to have large cisterns in the roof to lay in a stock of water in case of accident. When the water has to be provided by the building owner himself (such a contingency must be borne in mind when selecting a locality, as the water will have to be collected

from springs in the land, and very often gravel and rock are the only strata in which springs exist), a well has to be sunk in a position selected on account of its springs and freedom from risk of contamination by the surface water and drainage. A well should always be in ground at a higher level than any drains, cesspools, etc., and it should be sunk to such a depth as will ensure a plentiful supply in the driest of seasons, and there are cases in which small reservoirs are necessary, or a series of wells arranged to act as feeders to the main one.

It will be found necessary to pump the water up into the cisterns of the house, and the frequency of the pumping will be regulated by the demand for water, the extinguishing of an outbreak of fire not being lost sight of.

Where the main well exceeds 25 feet in depth, a force-pump will be necessary, and this should be driven by power—in fact, it would be better to supersede manual labour in any case. This can be easily and inexpensively accomplished where electric power is used for lighting and other purposes. There are instances in which the pumps have been worked by a small windmill, but its action is uncertain from variation of the wind.

Lighting is another important consideration, especially in a rural district, where very probably there is no gas service, and even where this is available it would be of advantage to utilize it only to drive a gas engine to promote power for creating electricity, which will be found of incalculable utility in pumping water and driving laundry and stable machinery, in addition to supplying light. The electric light is not much more expensive to install than gas when a new building is being dealt with; besides which it is less risky in causing fire, is healthier, and does not destroy the internal decorations in so short a time as gas.

Where gas is not available to drive the engine, the provision of coal, oil, or other fuel should be considered; but on the other hand a river or waterfall may be utilised to provide the power to create the electricity.

Acetylene gas and oil are two other illuminants open to the householder, but they are nothing to be compared with electricity and ordinary coal gas, besides which the risk of explosion is greater with acetylene gas, and lamps are a terrible nuisance.

Acetylene gas is laid over the house by piping in exactly the same manner as ordinary coal gas, and it is generated in a separate building erected for the purpose.

Accessibility.—This point relates to the supply of the building materials, during erection, and afterwards to the carriage of coal and other necessaries required during occupation, and it is always worthy of consideration.

A town and railway should also be within easy reach to render a house above reproach, and it may be worth while to look at the selection of a site from the point of view of providing sport and occupation, as opportunity for hunting, shooting, fishing, golfing, and other recreations is a valuable asset which often brings a purchaser when one is required. The writer is of opinion that everyone who purposes building a house should not lose sight of such a contingency, and he should not, except under specially good circumstances, build a house for himself only—a house in which fads and fancies are met with at every turn which as a rule are only of value to one person.

Having obtained the ideal site fulfilling most, if not all, of the favourable conditions hereinbefore enumerated, the client instructs his architect to prepare plans embodying his requirements and wishes, and when the plans, elevations, and sections have been finally completed and approved of,

he will do well to instruct his architect to have quantities prepared and estimates sought from selected builders, in preference to advertising for tenders from any and everybody —a course which oftentimes only leads to trouble and ultimate loss.

An endeavour will now be made to call attention to the points and details of the building to which consideration is due in attaining the ideal dwelling sought, and it should be understood that the advice to be given is for the ultimate welfare of the erection and its owner; and although it may mean increased expense in the first instance, yet experience has proved that a good thing well done is always a good thing, but the contrary has either to be endured or made good, sooner or later, at the cost of a bad and a good article combined—to say nothing of the attendant worry and dissatisfaction.

In the planning of the rooms and arrangement of doors and windows, it is important that the position of the furniture be assigned, particularly in the case of the bedrooms. The bed should be in a healthy position not far from the fire, the washing-stand hidden from the door and windows, the dressing-table convenient for light and unseen from the door. The bath-rooms and w.c.'s should be placed in positions on each floor convenient to all rooms, easily to be found and yet not in obtrusive places which are passed by everybody in the house, and each should be provided with a properly ventilated intercepting lobby.

Foundations and Cellars.—The nature of the natural foundation must first be ascertained, and if it is not adequate to support the superstructure it must be made sufficiently strong by artificial means.

Rock, gravel, and a good stiff clay as a rule are good enough to carry any ordinary building provided the weight

of the superstructure is spread and distributed over a sufficient area, and it should be noted that all foundations should be not less than three feet below the surface, out of the reach of atmospheric influence, which is particularly noticeable with clay, a material acted upon seriously by both excessive wet and extreme heat.

With foundations in any strata other than rock, gravel, and clay, the concrete must be sufficient in width and depth to carry the building, and with sand and other compressible subsoils it is often advisable to spread the concrete more than by the rule hereafter given, for a little care now will obviate the unequal settlements which gradually appear in time and spoil the building.

A good rule is to make the bottom footing in brick or stone equal in width to twice the thickness of the walls at the ground floor, and to spread the concrete out six inches further on both sides, and the footing courses should be built with the bricks in heading courses and the stones in large flat bedded rubble. The wall should then be brought up to the plinth level, which varies from six to twelve inches above the general surface, and care should be exercised that the interior of the walls are well flushed up with or grouted in the mortar specified, a detail which is too often neglected in the work below and above ground, especially in cellars and outer walls exposed to unusual driving rains.

If the ground shows signs of retaining moisture to any degree, it would not be undesirable to build the cellars in cement mortar, and if water is in evidence and likely to be pressed against the walls by higher ground, etc., it might be necessary to render the exterior of the outer walls below ground with a coating of asphalte or cement (the former preferably), and cases have been known where it was

necessary to carry the asphalte under the floor to enclose the cellar in a "tank," so that water could not rise, enter, or be driven in under pressure. In addition to these precautions an open field drain, covered with wheat straw, at the bottom of the wall, with the filling in up to the ground line executed in broken rubble, will often relieve the pressure, and the water is then conducted away from the building.

Damp-proof Course.—Having got our work up to plinth level or thereabouts, the damp-course would be spread in one unbroken surface over the whole of the walls, under all woodwork, and three or four inches above the outside surface, and this layer should be in some impervious material similar to asphalte or slate in cement, and such as will effectually preclude the ascent of damp.

The main or outer walls are then built up to the roof in varying thicknesses to suit the different requirements, and it is always a boon to build the external walls of such a thickness that the interior of the house is warm in winter and cool in summer, and what is more important still, proof against driving rains, but this cannot be obtained in the south unless the walls are at least fourteen inches thick for brick and sixteen inches for stone ; and in the northern districts, subject most to driving winds and rains, it is necessary to make brick walls either eighteen inches thick solid, or sixteen inches thick with a 2-in. cavity between the 9-in. and 4½-in. brick leaves or skins, and for stone walls the thickness should be twenty-one or twenty-two inches, with three-quarter bonders in preference to "throughs" where the stone is in any way porous.

It should be understood that the cavity, when ventilated at top and bottom, is an excellent non-conductor of heat, cold or rain.

Of course there are other means of preventing the penetration of damp—such as vertical tiling, or slating, or cementing to the exteriors; but all these are more or less unsightly and subject to their suitability and adaptability to architectural treatment, and, in addition, coatings of patent waterproof solutions are applied to absorbent bricks and stone to get rid of the suction present.

Sometimes asphalte or other impervious material may be with advantage poured into the vertical cross joints to form as it were an inner coating; but this is, like "flushing up" and "grouting," very apt to be forgotten, and, unless the coating is complete and continuous, it is of little use.

Damp is also experienced where parapet walls and water tablings or copings are used at the top of gables and gutters; the wet, of course, descending and soaking through the bricks and stone. Trouble from this source may be prevented by a damp-proof course of asphalte or other pliable impervious material, laid on the walls underneath the copings and just over the flashings, a similar remedy being used where the wet has descended at the chimneys.

Bricks.—Common bricks can be procured nearly everywhere, but their quality naturally varies, and the general defects to be avoided are the presence of lime and softness. A good brick should be hard and non-absorbent, giving forth a clear ring when struck with the trowel, a dull thud indicating softness and incomplete burning, which are defects not to be overlooked or passed over for any consideration. The presence of lime in any quantity also cannot be lightly considered, for the extent of its evil influence is far-reaching; it may burst and disintegrate the brick at any time, and moreover damages work such as plastering when applied to bricks containing lime; these must be avoided and cast aside forthwith.

Efflorescence, the white powdery film appearing on the surface of the brickwork, is due to magnesia or a sulphate or salt present in either the bricks or mortar, but as a rule it will disappear completely in course of time, except in districts where a supply of salt is periodically being impregnated into the walling by means of storms and wind from off the sea.

The bond in which brickwork is built should be either English or Double Flemish, the former being stronger on account of the greater number of headers used to form cross bond, while the latter is more sightly, particularly in facing bricks where the colour of headers varies from that of stretchers, a point readily understood when it is pointed out that in English bond we have a row of headers and a row of stretchers alternately, and in Flemish the stretchers and headers are arranged alternately in the same row or course.

Single Flemish bond should never be permitted on account of the snap headers necessary, the resulting walls being very weak on that account. A course or two of sanded hoop iron laid between the head of a lower floor window and the sill of an upper floor window, oftentimes proves an efficient longitudinal bond.

In every kind of walling, however, too little attention cannot be paid to the quality of the mortar, which should be made of materials that will set hard *inside* the walls as well as on the outside, where the air assists its setting. The best "poor" lime and sand in a locality oftentimes make inferior mortar, whatever attention be paid to its mixing and proportions, and it will occasionally be found that a poor lime (that is, poor in hydraulicity), and the best procurable over a very wide area, may be much improved by a good quality of sand, which at all

times should be sharp and coarse in lieu of fine; and furthermore, good clean ashes will often have a still more beneficial effect on the mortar.

A good mortar should set hard quickly both inside and outside the wall, and it should adhere to the bricks, especially at the vertical joints where contraction—perhaps years in taking place with a slow setting mortar—is apt to leave a very slight space through which wet is driven, the soft mortar inside absorbing and sucking it in, instead of forming an obstruction to its ingress.

A lime which has a certain amount of hydraulicity should be used in making the mortar, the additional expense of which is infinitesimal compared with the benefit received.

In the fronts or elevations of the building, a little care is required in the selection of facing bricks and stones, those being chosen which will absorb comparatively little water; it will be found that the capacity for absorption may be the measure of its longevity—especially where the sun is little seen or felt.

As a rule, it will be experienced that a stone lasts longer in its own climate and locality, and with sandstones there will be less absorption than with limestones, and the former will last longer in towns and near the sea. A sandstone is always more expensive than a limestone, but its durability is greater.

All stones should as a rule be laid on their natural beds, that is, the layer or bed of their formation in the same position as it was when in the quarry.

Another small detail worthy of careful attention is the bedding in of door and window frames; the jamb of the opening, parallel to the outside, should be screeded with haired lime all over, and the frame put up against it, and

then firmly wedged forward so that the pressure of the wind cannot move it towards the interior; the joint between the frame and the reveal should then be flushed up and pointed with mastic cement in oil.

All door and window frames should be set in reveal, *i.e.*, sunk back within the face line some 4½ or 9 inches, and the joint between the stone and wood sills should be made with an iron tongue let into stone and wood and well bedded in white lead, which should also be applied the full width of the wood covering the stone. All brick weatherings and projecting courses should be laid and pointed in cement mortar, and all stone weatherings should be as quick as possible, and the joints thereon "saddled," *i.e.*, raised thus to throw the wet away from the joints. (See Fig. 107.)

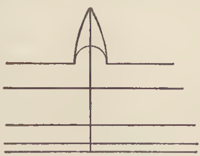


Fig. 107.

Projections, in whatever material, should always be "throated" on their underside to prevent the water from running down the walls, causing discolouration and damp. Water cannot ascend up the throat A, Fig. 108, and so it will drop off, a fact particularly noticeable in copings to boundary and other walls, as experience teaches us that the pointing of a wall not protected by a throated overhanging coping is always being damaged by frost, simply because the rain *pours* down its face and presents it to the action of the frost, which does not damage a dry wall.

Fig. 108.

Smoky chimneys can be avoided by attending to a few details, such as the building of well-twisted flues of one uniform size throughout, placing the chimney stacks on inner walls, and always having nine inches of brickwork between the inside of the flue and the atmosphere, or fire-clay flue

linings inside the $4\frac{1}{2}$-in. work, as a cold flue will often prevent the smoke from ascending. Furthermore, the chimney stacks should be carried up three or four feet above the highest ridge; the chimney pot should *not* have a reduced outlet; tall trees should be kept at a distance; and a windledge in the flue over the fireplace will reduce the down draught, while an inlet of fresh air will increase the up draught.

The Roof.—A good roof, with efficient foundation and walls, completes the exterior of a building, and with these three points and the floors in perfect condition (the other items of a building can be easily put right if found defective) the carcase can always be said to be sound.

All roofs should be constructed with good redwood, of sizes and arrangement adequate to the necessity of upholding the roof coverings in the condition in which they are first put on.

The details of naked roof construction have been explained in the first section of this volume, and it is important that the framing should be sufficiently strong to resist in a rigid state the most violent storms of wind and snow. Having attained that state of perfection, the client is now confronted with the coverings, the consideration of which is often decided by the design and the locality.

Flat roofs are covered with copper, lead, or asphalte, all good materials, more or less costly, but efficient, especially if laid on wood framing, with the boards running the way of the fall, and not across, to be raised up by the heat, and to cause a slight ridge which in course of time will lead to the lead being worn thin. Asphalte will crack when laid on concrete, due to the movement of the iron or steel work, expanded or contracted by the variation in temperature: hence wood joists, boards, and felt underneath, are the best.

Flat roofs always allow of snow lying, a fact which should not be forgotten in making the "upturns" against walls, etc. of adequate depth, and the evil may be further minimised by using snow trellis over the flat surfaces, which will form a latticed covering to support the snow and allow it to drain through the spaces on to the roof, when it becomes no worse than rain water to get away. Pitched roofs may be covered with slates or tiles, according to taste, and the pitch of the roof must be steep, *i.e.*, not less than 45 degrees for tiles, and 35 degrees for slates.

Tiles are non-conductors of heat, and slates the reverse, hence it is important that felt should be used under slates to remedy that deficiency.

Tiles and slates should have a three inch overlap, *i.e.*, the third one should lap three inches over the first one laid.

All slates should be nailed, with two stout copper nails to each slate, to redwood laths; and in exposed situations, tiles usually held up by nibs resting on the laths, should have every third course nailed, as a precaution against the tiles being lifted off in a gale.

Welsh slates are blue, and the Westmorland a beautiful green, the latter being twice as costly as the former, although there is no difference in their efficiency.

It is important in both slated and tiled roofs that all hips, ridges, valleys, and joints against vertical surfaces, should be made secure and watertight, leadwork of adequate strength being utilised in no unstinted measure, and all should have under-flashings of lead and be pointed up in oil mastic.

All vertical and inclined leadwork should have a lap of from four to six inches at each joint, and on the flat the joints should be made by means of drips and rolls.

It is often a matter of discussion when considering the character of the building to be erected, whether the eaves and gables shall be overhanging or flush with copings, and where such is not decided by the design proposed, it may be pointed out that overhanging eaves and gables have disadvantages in that they darken the house and keep off the sun. They also form a harbour for birds building about the place, and in very windy districts they provide an obstruction to the force of gales, cases being known where the wind has lifted off the roof by means of these projections and overhangings; on the other hand they have an advantage over gables in that they are cheaper, and not so likely to allow the wet to soak in.

Floors.—An ideal floor is one that is fire and sound-proof, and sufficiently strong for its purpose, with a covering suited to requirements—such as tiles for bathrooms, w.c.'s, corridors, and domestic apartments, wood of various kinds for sleeping and reception rooms—but such a floor is necessarily more expensive than the ordinary joisted floors met with in every-day life.

It is possible to make a wood floor fireproof and also sound-proof : in fact the writer is of the opinion that wood is the only floor that is fireproof, in the cases where the building as a whole is not seriously damaged by fire—we know that all woods char, and unless the charring is on all sides, and sufficient to eat away the whole of the wood, a certain solid and sound portion remains after the fire—in fact, this is proved at every fire where wooden beams have been used, whereas it will be found that steel or iron may not perish, but their form is so altered that during the fire they have pushed out the walls, allowing the other parts of the floor to collapse, while they themselves are so twisted out of shape that they are worse than useless.

Iron construction and concrete may be a benefit in resisting fire in that they delay the progress of the fire, and so allow of more chances for it to be subdued and overcome, but once the fire has obtained a complete hold the presence of the iron or steel is more a disadvantage than otherwise.

There are many patent floors said to be fireproof, but they are only fire-resisting, and certainly on that account are most valuable as a whole, but the materials employed are, as a rule, dangerous and unreliable under fierce fire.

It is a well-known fact that "cast iron" is unreliable under the variations of heat and cold water; that "wrought iron" and steel expand and bend as soon as they lose the coverings with which they should always be encased; and that the brick, stone, or breeze used in the lintols or the concrete is very unreliable: in fact, only in cases where smithy refuse or ashes which have lost all their combustion are used, can it be said that any material is fireproof.

On the other hand, a solid wood floor built up of joists side by side, around which no air can circulate, may be said to be fireproof, because it will only char one or two inches inwards from the side exposed to fire, and the remaining part will be sound, in addition to which no danger to walls can be apprehended from expansion or contraction, as none takes place. The only objection to such a floor is its expense and the limit of its spanning powers, but there can be no doubt of its superiority, and a saving of expense can be effected in the floor covering, as ordinary flooring can be used with the wood. For concrete it is always advisable to use block floors, which with their necessaries are nearly three times as costly, the concrete having the advantage where cement, tile, or asphalte floors are required.

Another essential in an ideal floor is that it should be proof against sound, *i.e.*, sound should not be transmitted from the room above to the room underneath, and both wood floors and concrete with iron floors are equally deficient on this point.

We have to look to space to remedy that defect, and an independent ceiling with an air space between it and the underside of the floor is all that is required. Furthermore, if constructed on fireproof lines with metal *thoroughly* embedded in plaster, such an air space acts as a protection against fire. The ceiling can be hung up to the floor and the air space will be very beneficial on both accounts.

In substitution of the deafening of various kinds in use

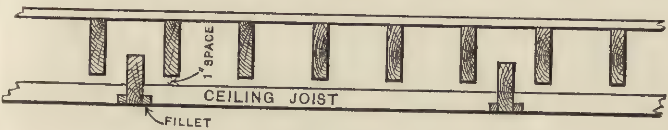


Fig. 109.

(and all of them are non-efficient, though they may be said to reduce sound), an independent ceiling may be used with advantage, and it will be found to stop all sound, and where it is not possible to erect a ceiling of fireproof properties, ordinary wood ceiling joists will give the same results as regards sound, the space shown on the Fig. 109 being the means by which the sound is checked.

Areas and staircases may be considered channels by which fires are spread and fanned, and on that account should be constructed as far as possible with fireproof and fire-resisting materials.

A frequent cause of fire where ordinary wood joists are used is the substitution of a concrete hearth in lieu of the

brick trimmer arch, which only costs a few shillings more and should always be insisted on.

Ventilation to the ends of Timbers.—All ends of timbers built into walls should be tarred, and left open for the free circulation of air, if they are flushed up with soft mortar they are apt to become "rotted," and under all ground floor joists there should be a constant and free current of air to prevent the fermentation which causes "dry rot," and it is important that the current of air penetrates to the corners, for if any stagnation takes place there dry rot will begin at the corners and spread very quickly over the whole floor.

Lime Concrete.—It is advisable to cover the surface of the ground underneath with a layer of lime or cement concrete so that the growth of any vegetable matter is rendered mpossible.

Partitions.—The plans of the upper floors often do not allow of the walls of bedrooms coming over the walls beneath, a contingency due to the necessity of having reception rooms larger than is necessary for bedrooms; in such a case the divisions cannot be made of solid brick or stone unless they can be supported by beams or girders, the latter of which, unless thoroughly protected, are always a source of danger under fire.

It is usual to make these light divisions of wood, plastered both sides; but they are neither fireproof nor sound-proof,

Fig. 110.

and in addition prove a harbour for rats and mice. The second defect may be obviated by the use of double studs as in Fig. 110, which provide the air space necessary as a

non-conductor—still there remain two serious blemishes to an ideal house. The desired alternative is supplied by several newly patented solid partitions, which are thin, light in weight, sound-, fire-, and vermin-proof, and with fire-proof floors they are rendered free from objection.

The partitions may be constructed with thin interlocking bricks or hollow blocks of plaster, connected together by dowels or wires, and the outer surfaces are coated with plaster similarly to the walls, or the groundwork may be of expanded metal lathing strung up to the floors and ceilings, and stiffened when necessary by rods ; the metal is then supported from one side and plastered on the other with a quick-setting plaster or with the ordinary haired mortar gauged with one part of Portland cement to three of mortar ; that side is allowed to dry, and then the other side is treated in the same manner, the result being a solid stiff partition two inches thick, plugs being inserted during plastering for affixing the joinery etc.

All these patent partitions are much more costly than the ordinary stoothing or studded partitions, but, on the other hand, the latter has no advantages and is always a source of dissatisfaction, while the former really cost no more than solid walls, and certainly take up less space.

Windows.—The windows of a house are an important detail, and plenty of light is very essential in every department of a dwelling.

Window openings should be not more than from 24 to 26 ins. off the floor, and only a few inches below the ceiling, because the foul air of a room always ascends to the top and requires an outlet to maintain a healthy atmosphere in the room, and unless there are special means of ventilation the top of the window supplies the only egress for the vitiated air.

Another detail to be observed is that the meeting rails

of the sashes should be above the line of sight, *i.e.*, they should be, when closed, above the level at which the eyes of an average person, when standing, would be in looking out of the window. If the line of sight, when one is standing up conveniently, is interrupted by wood, it causes both inconvenience and annoyance, and only a little care is required to avoid this.

Window openings may be filled up by either sliding sashes—moving up and down—or by casements opening inwards or outwards, or by metal casements fixed to the stonework without the aid of wood frames, to which the sashes or casements are affixed.

Dealing with the metal casements first, the objections to their use may be said to be their cold and comfortless appearance—points which can hardly be overlooked in a dwelling, however good their other properties may be—and undoubtedly very fine metal casements can be bought at a price, and the advantage of them is that they (the good ones) neither rattle nor let in wind or rain.

Wooden casements, in common with metal, when made to open inwards often interfere with blinds, curtains, and other furnishings, and when they open outwards there is a difficulty in cleaning all except those close to the ground. When casements are made in wood, they are much cheaper and look homely and comfortable from within, but on the other hand they are very difficult to make water- and wind-tight, although such a detail is not impossible with a great amount of care in designing and executing the details. Wind and rain *will* drive in during gales, and they require no end of checking by rebates, hollows, and weather bars, in addition to which their fastenings must be put on very carefully to allow of "tight fits," so as to prevent rattling as well as the wind and rain getting in.

Cased frames with sliding sashes are undoubtedly the best window, and are moreover the cheapest, but when made with indifferent and unseasoned wood are most irritating, because they not only let in wind and rain (though not so much as wood casements) but they rattle very much, which defects, however, can be cured by making the styles of the sashes and the parts in which they slide up and down in well-seasoned teak—a wood which does not swell or shrink to any perceptible extent. The meeting rails should be properly "checked and locked," and the bottom rail of the lower sash so constructed that the wet cannot be driven in. It is also better to make the sills in oak, as the sills are the first to rot, and unless in oak or teak the frame outlives the sill.

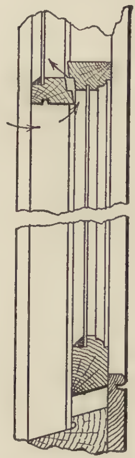


Fig. 111.

It is important that sashes be fitted with first-class axle pulleys, Italian hemp cords, and suitable weights, and that a sash fastener be used that does not lend itself to being opened from the outside.

Sashes can be easily cleaned; they do not interfere with blinds and curtains; and in addition, if a deep inside bead is employed over the sill, the bottom sash can be partly opened to allow for an inlet of fresh air without draught, as in Fig. 111.

Where a room or office is required to be kept free from sound it will be found very beneficial to have another set of sashes inside the outer one, with an air-space between.

Window Finishings.—In designing the finishings, whether they be the ordinary linings or boxing shutters, it is important that a space of two and a-half inches be left for the blinds

to work easily up and down (splayed linings are awkward for fixing the blinds), and it is very inconvenient to have to draw up the blinds before the shutters can be closed—a contingency often met with—while the linings to the jambs should allow of a couple of inches of blind going each side the glazed sash, or it is possible to look into the room from outside after the blinds are drawn.

Doors.—Doors are not so open to irregularities as windows, the only points requiring attention being (1) that they are made of well-seasoned dry materials—yellow pine being preferred for wide panels; and (2) that they are of sufficient thickness and strongly framed together, so that there may be no sagging from their hinges nor twisting at top and bottom —defects that soon make the door useless, because it will not fit the rebates into which it is intended to close. The panels should also be allowed freedom in the grooves to come and go according to the season, or they will split up the centre, for even the best and driest materials will be affected by the atmosphere —swelling or contracting as it rises or falls.

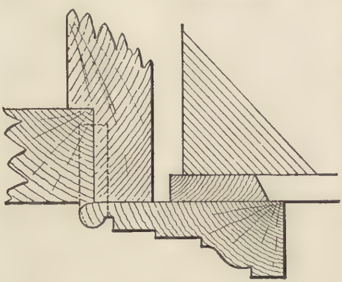


Fig. 112.

Other essentials are—(3) that they are large enough in width and height to admit the furniture into the rooms; and (4) that they are fitted with good hardware or ironmongery. A client cannot throw away money on locks which practice has proved are good, efficient, and simple in their working, it being better to spend more on the lock and less on the ornamental furniture.

In hanging a door, the thickness of the carpet should be known and worked to, and the butts should be sunk into a bead on the casings or architrave, as in Fig. 112, so that when the door is partly open a space is not available for peeping into the rooms.

Stairs.—An easy "go" to a stair is very desirable, as it should not be necessary to grasp the handrail when ascending to keep from falling back. A wide tread needs a small rise, and a 10-in. tread should have only a $6\frac{1}{2}$-in. rise: in fact, for ease, it is well that the tread and rise multiplied together should not exceed 66.

A landing or resting place should occur every eight or ten steps, and the underside of all steps should be glued and blocked to prevent creaking. If the stair is wide, they should also be supported intermediately between the strings by carriages and brackets.

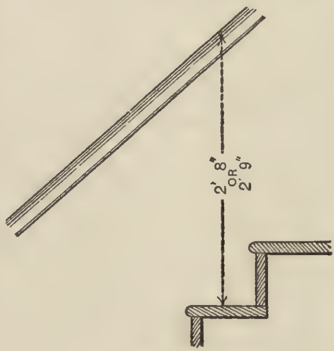


Fig. 113.

The handrail should be at a convenient height, generally as in Fig. 113, and it should have no sharp edges and be not too large; it should be one that can be easily grasped in case of need.

In addition to the foregoing details, a staircase should be well lighted, having no dark corners, and winder steps should not be permitted. It is always well, also, to have the foot of the stair obscured from the front door, although in a prominent place.

Other Internal Finishings.—Chair rails and picture rails should be of sections convenient for use, and the former without any arrises or edges to get damaged by wear.

All dadoes should be painted behind to preserve them, and behind them and all skirtings, strings, etc., the spaces should be flushed up with plaster to prevent a harbour for vermin being formed. The bottom members next the floor should be let into a rebate in the floor-boards, to obviate the unsightly and unhealthy cracks often observed from shrinkage, and it is not undesirable to have a small hardwood fillet fixed to the floor at the foot of them to prevent the legs of chairs damaging the paint work.

All architraves and joinery should be fixed to grounds plugged to the walls, and in hardwood all work should be secretly fixed and with slotted screws where possible.

Skylights.—All roof lights should be provided with means for the condensation water to get away, because in cold weather great inconvenience and damage result from the condensation. It can either be collected into a gutter at the bottom of the glass and then taken out by means of a pipe, or the bars may be double checked, as in Fig. 114, the groove carrying the water away.

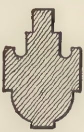


Fig. 114.

In addition to the condensation trouble, one always has to face, with skylights, the further possibility of decay to the putty which holds in the glass; the varying effects of the sun and rain causing it to become useless. Provided the glass is well bedded down in putty on the rebates, the less putty one uses the better: in fact, horticultural builders, whose province it is to deal with glass lights more than anybody else, often use no putty on the top of the glass; but where putty *must* be used on the top it should be protected with a capping of teak or yellow

pine, which should be screwed down with brass cups and screws, the iron ones having a tendency to split the wood.

Skylights when required in any number are often constructed under patent systems, the object of which is to remedy the aforesaid defects.

Internally.—The internal walls of the building are, as a rule, plastered with ordinary hair and lime mortar, which forms a level smooth surface on which papering, distemper, and paint can be put, but the finish of the work should be different, as papering does not require that smooth surface which is required for paint and other similar coatings. The latter needs a finish called trowelled stucco, *i.e.*, the surface is rubbed over with a steel trowel, whereas for paper it only requires finishing with a wood float.

All ornamental work and mouldings should be finished white in putty, and any member likely to be subjected to hard wear or rough treatment should be backed up in Portland and finished in Keene's cement. The best work for painting of superior quality should be finished in Parian cement, or in Albino, a new cement which sets harder and quicker and wears better. It is desirable that all plaster cornices and horizontal mouldings should be of such form that dust may not collect or be retained by them.

In cases where it is necessary that the drying of the plaster should be hastened, the usual remedy has been to "gauge" the plaster by adding with ordinary stuff a fifth to a third of its bulk of plaster of Paris, a material which sets very fast; but of late years several patent covering materials, in substitution of the ordinary stuff, have been brought out—such as Adamant, Ward's Cement, etc.,—but though effective they are very costly when used at any distance from the manufactory, owing to the carriage of the material, and an excellent substitute for them where the

cost is prohibitive is the Albino, which consists of a thin coating of that material put on a floating of ordinary local sand and Portland cement.

All the aforementioned can be put on to laths, but "lath and half" quality should always be used, and they should be properly bonded, *i.e.*, the longitudinal joints should be broken.

Bath-rooms, lavatories, w.c.'s, larders, and pantries should have their walls faced with glazed bricks, tiles, or other non-absorbent material, the bricks being of necessity built in as the work proceeds, whereas the others are put on afterwards on the top of coatings of cement and sand, which are employed to strengthen the walls and form a truly level surface, and, with very few exceptions, tiling, on account of its fine joints, is preferable internally to bricks, especially if "safety back" tiles are used.

The floors of these apartments should be of cement, tiles, mosaic, or terrazzo, and all angles to floors and ceilings, as well as walls, should be hollowed, so that there may be no corners or crevices in which dust can accumulate.

Sea sand should never be allowed, on any pretence, in the plastering of a house, as the humidity of the atmosphere affects the salt it contains, but there can be no objection to "drift" sand—that is sea sand drifted beyond the reach of the tide and thoroughly washed clear of salt by continual rains extending over a considerable time.

All water pipes in the ground should be three feet below the surface, to prevent them being frozen, and as soon as they enter the building they should be controlled by a stop cock to shut off the water from entering. Immediately above the stop cock a bib tap should be placed, so that the water can be emptied out of the pipes in the house when required, and whenever possible, as a precaution against

freezing, all pipes should be covered with stout hair felt tied round them by copper wire.

The rising main should be taken on an internal wall up to the cistern in the roof, such cistern being of slate, galvanized iron, or wood lined with lead, and of adequate capacity to suit the case of either constant or intermittent water supply.

The material of which the cistern should be made will depend on the constituents and quality of the water, lead and the alloy used in galvanizing being sometimes affected by the water, through chemical combination, to such an extent that the water becomes tainted and poisonous, and it is often necessary to have separate cisterns for different purposes.

The drinking water cistern should always be covered over, to prevent dust and dirt falling into it.

The entry of the water into the cistern should be controlled by a valve and copper float, and the outlet should be freed through a large overflow pipe discharging outside the building, in a conspicuous place where any serious waste of water would be soon noticed.

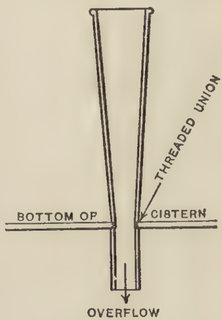


Fig. 115.

Every cistern should also be provided with a sludge pipe put in at the bottom to allow of the emptying for cleansing purposes, this sludge pipe being closed by a stop cock, and it should discharge into an eaves gutter or rain water head; or, better still, a standing waste should be employed, so that the overflow can be utilised for sludging purposes, the movable standing waste being trumpet-mouthed (see Fig. 115), and attached by a screwed union in the *bottom* of the cistern.

The water supply of a house should be taken from the cistern, the outlet being a few inches above the bottom, and it should be controlled by one stop cock under the cistern and others at other positions as required. It should not be forgotten that the supply pipes should be larger than the rising main, for the latter often has considerable forced pressure, and the former only that due to the head of the water in the cistern; and it is always desirable to have the sanitary appliances of a dwelling quickly filled, which can be done easily with $\frac{1}{2}$-in. pipes off the main under pressure, but a $\frac{3}{4}$-in. pipe should be used for w.c.'s, lavatories, etc., and 1-in. pipes for baths where the supply pipes are taken from the house storage cistern.

Water Closets.—The apparatus should be of an up-to-date design on the wash down principle, the pan containing plenty of water with a large top surface, and the trap should be provided with a large seal to prevent foul air getting into the house. The joint between the apparatus and the outgo should if possible be under water, *i.e.*, in such a position that, if faulty, the water will ooze out and show its defectiveness, for if water can get out it is pretty certain foul air can do so also. The lead outlet should be connected to the iron soil pipe by a brass ferrule soldered to the lead, and staved to the iron with yarn and molten lead.

The top of the arm of the trap should be ventilated by a puff pipe connected to the soil pipe by a brass ferrule, and the soil pipe should be of $\frac{1}{4}$-in. or $\frac{5}{16}$-in. metal, coated inside, when hot, with Dr. Angus Smith's solution, and every joint should be socketed and staved with yarn and molten lead, the soil piping being carried up as high as the ridge as a vent shaft. The top should be provided with a domical grating, to prevent birds and snow from blocking up the pipe. Lead soil pipes are

superior, but more costly than iron, which, however, perishes in time.

The flushing cistern should contain three (certainly not less than two) gallons of water to be used at each flushing of the apparatus, it should be glass lined inside to prevent rust, and it should be fitted with an adequate overflow.

The housemaid's closet or sink should be treated exactly the same as a w.c.

Lavatories.—The lavatory basins should be plain and cleanly, of large capacity and area, and fitted with overflow, trap, and cleansing screw connected to a "waste" discharging into an open head or on to a gulley outside; and furthermore the top of the trap should be ventilated by a puff pipe brought outside with a grating at its end.

Bath.—The bath should be of glazed fire-clay or vitreous enamel inside and outside, the vitreous cast iron bath being warmer than the fire-clay; each should be trapped and fitted with overflow pipe and fittings which cannot become soiled by neglect or carelessness.

All urinals should be trapped and fitted with a plentiful supply of water discharging continuously and flushing out automatically, and where a urinal is used on an upper floor it should have underneath it a lead or marble safe with waste to carry off any overflow: in fact, it would not be unwise to fit a safe under every bath and w.c.

Hot Water.—Every house should be fitted with hot water to supply baths and lavatories, in addition to which the run of the hot pipes is very beneficial in preventing the cold pipes from being frozen in winter, for which purpose it is advisable to run the hot flow and return pipes beside the rising main and supply pipes.

The supply pipe from the storage cistern to the boiler or cylinder should be one-inch diameter, controlled under the

cistern by a stop cock, and as a cylinder holding from thirty-five to sixty gallons, with a small saddle boiler, is better than a large boiler containing say twenty-five gallons, it is only proposed to treat of that system. The 1-in. supply pipe is brought down to enter just above the bottom of the cylinder, which may be of galvanized iron or copper, according to the nature and constituents of the water,

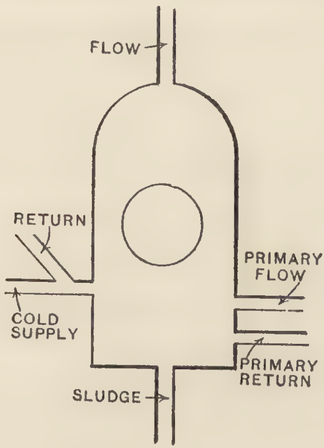


Fig. 116.

and should be placed beside the kitchen chimney breast, just below the ceiling.

At a slightly lower level on the cylinder, the primary flow and return pipes to the boiler are attached by unions, as in Fig. 116, the flow being above the return, and it is important that these pipes should be large, not less than $1\frac{1}{4}$ ins., of galvanized iron or preferably of copper, and constructed with easy bends to lessen the liability to furr up. Hot water always ascends, and after entry into the cylinder it

goes off about the building in the "flow pipe," *always* rising, and when it has reached its highest point it should descend by a separate pipe, called the "return," to the cylinder, joining the supply pipe just before it enters the cylinder.

The baths and lavatories should be fed by a short piece of pipe off the flow, and at the height of the system there should be an exhaust pipe to relieve the pressure of steam when necessary, and this exhaust pipe should discharge over a cistern or on the roof over a gutter.

Every cylinder should have a manhole for cleansing purposes, and should be fitted at its extreme bottom with a sludge pipe, actuated by a stop tap for emptying as required.

In arranging the "run" of hot water pipes, it will be of benefit to run them around linen and cistern rooms, where they serve a most useful purpose, and the more they are coiled in the cistern in the cistern-room, the more beneficial they will be in winter, though in summer they may be a nuisance; but the coil of piping can be controlled by a valve if due care is exercised.

The internal plumbing and hot water work of the house has been fully discussed, because the nearer it is to perfection the more comfortable and pleasing will be the occupation of the house in winter and summer; and although it may be said that expense has not been spared, it will be found that true economy, utility, and comfort have been placed first; and when one remembers the annoyance, damage, and loss often occasioned by lack of attention to some of the aforesaid details, the writer is sure the money will be considered to have been well spent.

If the water is injuriously affected by running through lead pipes, it is advisable to have them lined with tin; so that the area of lead in contact with the water is reduced to a minimum.

In cases where the ordinary water is hard, it is recommended that the rain-water be collected off the roofs into a large cistern, or where this is not practicable into a tank below the ground: it is then pumped up into a cistern in the roof and supplied therefrom through separate pipes to the baths and lavatories about the building.

Gas.—The gas system of a house should be always executed in wrought-iron piping, for it costs very little more and obviates the risks of leakages and explosion, which are always attendant when lead and composition pipes are employed, because it is impossible to see the pipes when they are embedded in the plaster, and how easy it is to drive a nail into a lead pipe when hanging or fixing something to the walls!

It is important that the supply pipe from the main to the meter should be of ample capacity, and from the meter the main pipes should be adequate to supply sufficient gas to *all* the lights fed by the branches therefrom—it is better to err on the right side in this matter, and often advisable to allow for a few gas fires, so that a poor light will not be the rule when most light is required.

Lightning Conductor.—Every isolated house of any size and height should be supplied with an efficient lightning conductor able to convey the destructive element into the ground without damage to the building. Conductors are usually made of copper insulated from the building by their means of attachment, and they should be thoroughly tested before taken over.

Electric Bells.—Every room and external door of the house should be supplied with an electric bell, ringing in a frequented place, and indicating the room from which the bell is being worked. Each bedroom should have its bell near the bed; in the bath-room it should be near the bath; and

it is convenient in reception rooms to have the bells in some other convenient place besides that next the fire.

Electric bells are infinitely better than the old-fashioned bells, with a different tone for every room, and furthermore they are immeasurably more convenient, especially when we consider that by means of flexible wires they can be placed anywhere: in fact, it would be possible to carry them about the room in your pocket.

Electric Light.—This means of lighting is on many points superior to gas, and when well installed is less risky than the latter, but when arranging for an installation it is advisable to insist that the whole of the materials and workmanship shall be of a class able to successfully pass the rules and inspection of a stringent fire insurance office.

Having secured work carrying such a certificate, pertaining to the wiring and to the plant for making and storing power for the same, one has only to arrange for the switches, brackets, and pendants supplying the light to be in the most convenient positions, it being only necessary to point out that electric light is more amenable and flexible than gas, so that it need not be near the walls and ceilings, a consideration which always allows of it being placed over dressing tables, near beds, etc., in which positions it is exceedingly convenient.

Painting.—All woodwork in or outside a house must be coated with paint or varnish in order to preserve it, unless it is of a hard wood which is usually polished. Woodwork to be varnished is usually of a selected kind and better class, having the grain and figure in some prominence to take away the monotonous and lifeless appearance.

Varnish is a hard transparent glossy coating, which should be applied after the wood has been sized—*i.e.*, the suction in the wood should have been satisfied by the appli-

cation of one or more coats of "size"—and oftentimes the wood is also stained to a tint (more or less unnatural) suited to taste, and then in good work it should have two or three coats of good copal hard varnish. The advantage of staining and varnishing is that it has a longer life than ordinary painting and does not get soiled and worn, but on the other hand the re-painting of a house renovates it and gives it an entirely fresh and changed appearance—a point unattainable with varnishing.

In stained work it is important that the work should be finely sand-papered and cleaned; all members fitting into others should be stained all over before they are put together, to prevent shrinkages, which it is impossible to avoid even with the best of woods. For instance, the panels of all framing should be stained before the framings are wedged together, or at every shrinkage a light coloured margin would be shown up the panels, and such a defect could not be satisfactorily remedied afterwards. Regarding ordinary painting it is most necessary that the preliminary work should be done well and effectively with the best of materials, as once done well it is always possible, at little expense, to remedy subsequent defects, whereas on the other, if the first part is done badly, nothing but starting afresh will overcome them.

First of all, all knots should be stopped with good patent knotting, which it is known by experience can kill and dry up the resin in them, after which a good coat of priming containing pure genuine old white lead should be applied in no scanty measure, and it is possible for anybody to check such material when being applied, for the painter's can is *heavy* with the genuine article, whereas the poor kind of material, little better than a water stain, which is sometimes applied, weighs light.

Having secured a good coat of priming, the work should be well rubbed down with pumice stone, and all slacknesses stopped up, and then another good coat of white lead paint applied, after which it should be again well rubbed down, and it will be found that if this is all done properly the other following work will be successful.

In newly-built houses it is not advisable to finish off at first the work just as it is ultimately intended to be, but to give the work three good coats and then let a year or two elapse before finishing off, as it will be found that during that time, the wood will have assumed its normal condition by the necessary contraction and expansion which always takes place, and when this has occurred, it will be time to complete the work, which can be further improved and made more lasting in its perfection by the addition of one or two coats of varnish.

It is not an unwise principle to have each coat of paint selected in a different tint, and to allow of good materials—light or pink colours are desirable—for no man can use light coloured materials to make dark colours, which may be readily understood when it is pointed out that the "body" of paint lies in its white and red lead.

The same remarks regarding the finishing off of new houses applies to the papering, for it is most foolish and extravagantly reckless to put good papers on to walls that are perhaps not truly dry, and what is worse, on to those which have "live" lime in their plastering ; for bright colours are much affected by lime, in fact—a blue or green wall paper will become completely spoilt in so short a time as two or three days, and yellow is sometimes affected.

In a new house it is wise to distemper or duresco the plaster work, or to put on suitably coloured lining papers to last the first two or three years, after which the house

can be decorated well without fear of the work being soon destroyed. Ceiling papers are generally light in colour and free from tints likely to be injured—hence they can be done at any time. It will be found that it is much to be preferred that ceilings be covered with paper, Anaglypta, Cordolova, or Lincrusta, instead of whitened or painted, both of which require frequent renewing—a process which generally damages the other work in the room, while with paint the cracking of a ceiling, oftentimes almost unavoidable, is soon in evidence to spoil the whole.

Glass.—The material through which everybody has to look should be of the best kind, free from bubbles, waves, and specks, and as such perfection is not often attainable with sheet glass, it is important that the sashes most frequently used for observation should be glazed with polished plate glass, of which there are several kinds suitable for household purposes, the most common being about $\frac{1}{4}$-in. thick, and the better qualities $\frac{3}{16}$, $\frac{1}{8}$, and $\frac{1}{12}$-in. thick.

The irregularities of sheet glass are noticeable from the exterior as well as the interior—especially when in the sun—for what adds to the appearance of a window more than good polished plate glass! Plate glass is made out of better materials, and is subjected to a more rigid selection—hence its superiority, in addition to which it cannot easily be cut by a "diamond," an objection in the eyes of the burglar. On the other hand it is heavy and makes the sashes cumbersome, but the thin and more expensive qualities obviate that.

The windows of secondary rooms and the top lights of others can be glazed with sheet glass, and all skylights should be glazed with strong polished plate, or rough cast or rolled plate, the latter being preferable, as they diffuse the light more readily.

All glass as a rule coming cut to size from the manufacturer or wholesale merchant, the glazier has only to take care in glazing that every sheet is well bedded in putty and pressed home into that material, after which it is sprigged and pointed with putty—wet often penetrates into a house through defective bedding of the glass—and the sashes should always have had a coat of paint before being glazed.

Leaded lights can be made with any glass and to any design, but it is important that the lead cames be sufficiently strong and wide enough to keep in the glass, and all edges of glass should be secured into the grooves by a cement run in on both sides. When fixing, the lights should be made rigid by substantial saddle bars, to which the lights are secured by wire and solder.

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